INSTREAM FLOW REQUIREMENTS OF THE LOWER NORTH FORK, SOUTH FORK AND MAINSTEM SKOKOMISH RIVER

UNITED STATES DEPARTMENT OF THE INTERIOR

Fisheries Assistance Office

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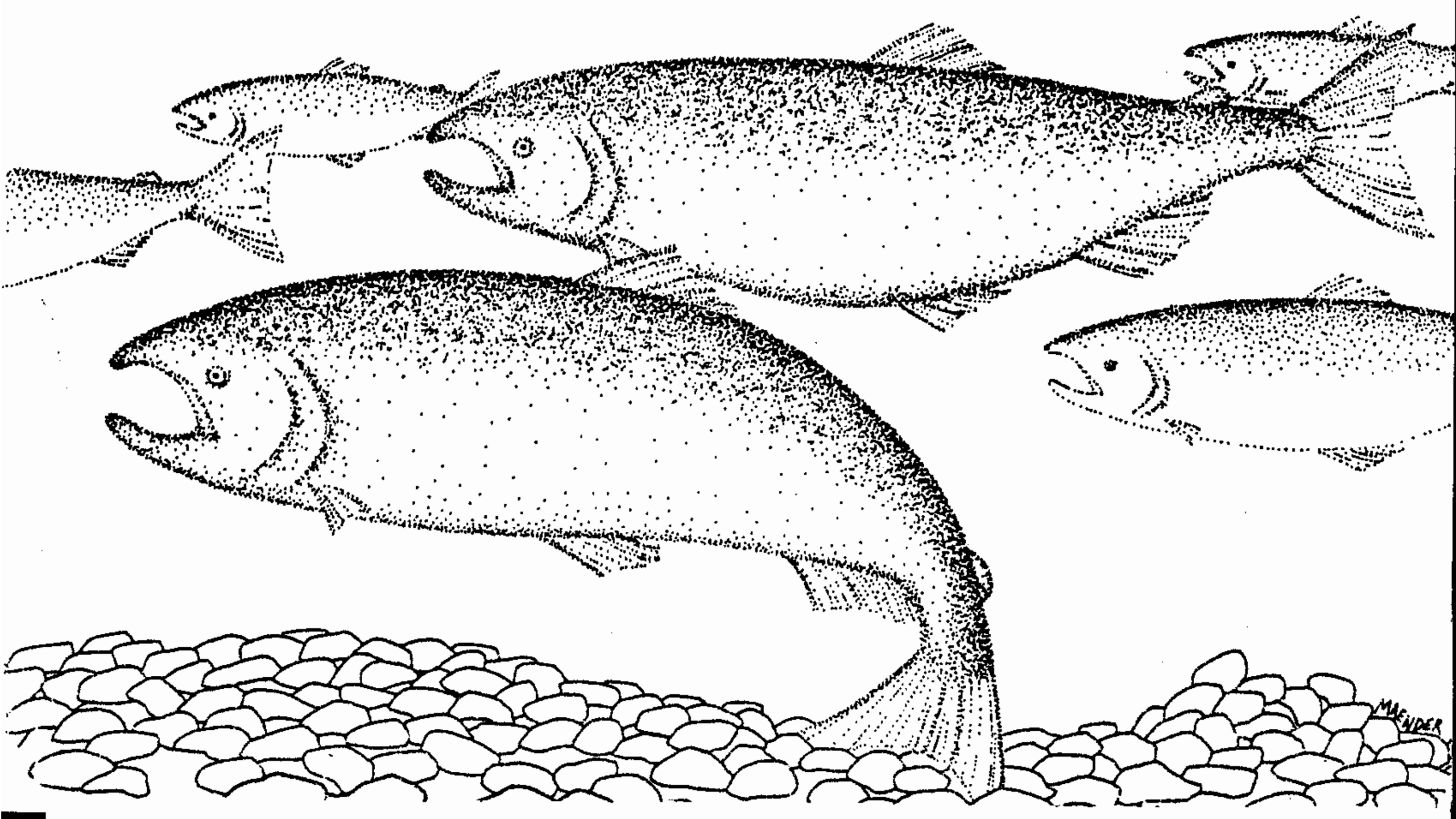
Olympia, Washington



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by
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May, 1980

ACKNOWLEDGMENTS

Many people helped to make this report a reality, and I wish to express my sincere gratitude to all of them. Mr. James Mullan gave me the opportunity to study instream flows in the Skokomish River, provided encouragement through the first days of field work, and commented on the draft report. Mr. Robert Ringo also provided encouragement, and assisted in shaping this report to its final form.

I owe special thanks to Mr. Robert Milhous, of the Instream Flow Service Group (IFG) staff. Bob spent many hours confronting a computer, and patiently demonstrating that all the numbers we input did, in fact, produce meaningful output. Mr. Ken Bovee, IFG staff, also provided essential advice and guidance.

A number of fellow biologists and professionals reviewed a formidable (i.e., having qualities that discourage approach or attack) draft report, and provided useful comment: Mr. E. Eric Knudsen (FAO, Olympia); Mr. Robert Wunderlich (ES, Olympia); staff of Skokomish Consulting Services; Mr. Robert Gerke (Washington Department of Fisheries); Mr. J. Gary Fenton (Washington Department of Game); and Mr. Hal Beecher (Washington Department of Game).

I am particularly grateful to YACC enrollees Chris McIntosh and Cindy White for their assistance in making instream measurements. Many members of the Olympia FAO staff provided occasional assistance in the field.

The report cover and most report illustrations were prepared by Mrs. Gloria Maender. I am indebted to Gloria for her attention to detail and continuing patience. Mrs. Gerry Bradford and Miss Carol DeMent performed many hours of typing. Their assistance is much appreciated.

ABSTRACT

The incremental methodology, developed by the Instream Flow Service Group (Ft. Collins, Colorado), was used to predict discharges that provide optimum area of suitable habitat for anadromous salmonids in the Skokomish River, Washington. Predictions are compared to time of occurrence of fish life stages and to equivalent flow year mean monthly discharges for respective river reaches. Time and deviation of mean monthly discharges in excess of or inadequate for optimum fish requirements are determined.

Optimum discharges for the lower North Fork range from 25-80 cfs. Five alternative strategies for controlling seasonal water releases from the Cushman Hydroelectric Project to optimize habitat area are presented. Recommendations are made to protect flow requirements at RM 9.8, historically subject to dewatering, and to protect all rearing fish upstream of RM 13.3. The latter reach should be seasonally protected by establishing a 25 cfs minimum water release from the dam.

Both lower South Fork and mainstem Skokomish River reaches have mean monthly discharges that typically exceed predicted optimum discharges for fish, thus reducing areas of suitable habitat. Comparison of lower South Fork predictions to those of the lower North Fork indicates that construction and operation of the Cushman Project reduced suitable habitat area below the dam by at least 80%.

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INTRODUCTION

The Skokomish River drains approximately 240 square miles of the southeastern portion of the Olympic Peninsula. It empties into Hood Canal near Union, Washington (Figure 1). At River Mile (RM) 9 the mainstem forks to become the North Fork and South Fork, referred to as "the forks." The Skokomish River system supports a large portion of the combined anadromous fisheries of southern Hood Canal. Historically, the system supported large runs of chinook (spring and fall), coho and chum salmon, lesser but significant runs of sockeye and pink salmon, and large runs of steelhead trout (James 1980; Deschamps 1957; Sandison 1977; Payne 1976).

The Skokomish Indian Tribe has always relied upon the river fishery for much of its livelihood. According to anthropological reports the Skokomish River anadromous salmonid resource supported at least 1,000 Indian people in pristine times (Payne 1976). The majority of these fish apparently utilized the North Fork Skokomish River (James 1980).

Early in this century Skokomish River salmon and steelhead trout runs began to decline because of heavy commercial fishing, primarily in Hood Canal. A commercial fishing closure in the lower two-thirds of Hood Canal was imposed during the early 1920's (Deschamps 1957), and Skokomish runs increased again until 1926. The fragmentary nature of fishing harvest and other records prohibits quantification of those runs.

North Fork Habitat Status

On the North Fork the Cushman Hydroelectric Project was completed by the City of Tacoma in December, 1930. The project consisted of Cushman Dam No. 1 with an adjacent power plant at RM 19.6, Cushman Dam No. 2 at RM 17.3 and, near the latter, a tunnel diversion to convey total river discharge to a power generation plant on Hood Canal. The upper dam enlarged a natural lake to 9.6 miles in length and 4,000 acres (City Light 1974). The lower dam formed an impoundment of about 150 acres (Photograph 1, page 7). Except during prolonged periods of heavy runoff, the entire discharge of the North Fork was diverted to Hood Canal (Morrison-Maierle, Inc. 1979). In 1953, to increase power generation capacity, the City of Tacoma constructed a small dam on upper McTaggert Creek (RM 4.1), a North Fork tributary downstream of the dams, and diverted most of its discharge into the river above the lower dam.

The resultant effects of the dams and the North Fork's diversion upon anadromous fish runs were severe. Many miles of spawning and rearing habitat were permanently barred from anadromous salmonids (Photograph 2, page 7). Prior to the project the affected river reach and its accessible tributaries, between RM 17.3 and about RM 29.8, supported steel-

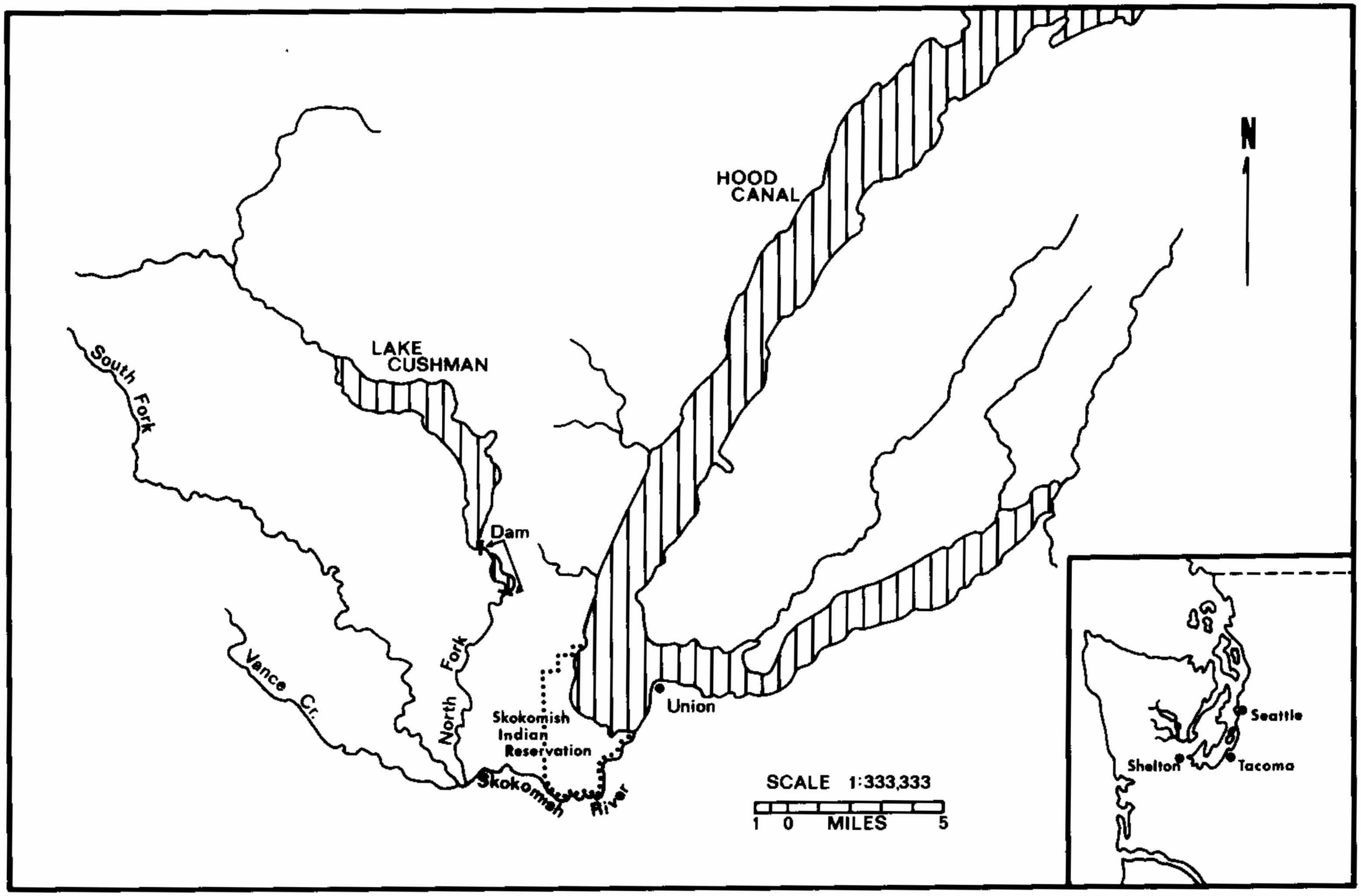


Figure 1. Skokomish River and lower Hood Canal showing locations of Skokomish Indian Reservation and the two Cushman Dams.

head trout, spring, summer and fall chinook, sockeye, coho and chum salmon (Deschamps 1957; Sandison 1977; Phinney 1973; James 1980). Steelhead trout, coho salmon and spring chinook salmon may have negotiated the cascade at RM 29.8 to gain several more miles of habitat. Following project completion, spring-summer chinook and sockeye were eliminated from the North Fork (Payne 1976) after having been denied essential holding, spawning and rearing areas required to complete their life cycle.

After the lower dam was completed and the river's flow diverted to Hood Canal via tunnel, the North Fork run of fall chinook was greatly reduced (Deschamps 1957). Lower North Fork discharge during late summer and fall is frequently too small to provide passage for adult chinook (Phinney 1973). Coho and chum salmon and steelhead trout runs were also significantly reduced (Payne 1976). Washington Department of Fisheries (WDF) stated that during low flow years all species of salmon are limited in their upstream migration to the lower one mile of the North Fork (Sandison 1977). This is the result of combined low flow and low water table conditions that cause a limited reach to dewater. Even more routinely North Fork flow is insufficient above the mouth of McTaggert Creek to permit access by chum and chinook salmon (Sandison 1977). In years of average to less-than-average winter precipitation the "lower falls," at about RM 15.6, apparently act as a barrier to upstream migration of coho salmon. Prior to dam construction the flow-stage relationship at the lower falls apparently permitted relatively easy passage for most anadromous salmonids.

During the period 1974-1978, the range of greatest fish-per-mile spawning ground estimates for the lower North Fork (RM 9 - 17.3) and tributaries were as follows: spring chinook, 0; fall chinook, <1 (1973); chum, 111-704; pink, 0; coho, 18-71; and sockeye, 0 (Egan 1978, 1979). Additional data (Wilbur 1979) gathered in December, 1978 were: chum, 284; coho, 6. Equivalent information on steelhead trout is not available.

Water quality analyses performed in the Skokomish River system suggest that all parameter levels are acceptable for salmonids (Kramer, Chin and Mayo, Inc. 1979). In the lower North Fork, however, the greatly reduced levels of discharge in turn reduce the ranges of available water velocities and depths; and reduced water volumes are more subject to the influence of ambient air temperature. In addition to the direct adverse impacts of the project, there have been numerous indirect adverse impacts (Table 1).

A combination of adverse impacts have provided the beaver, *Castor canadensis*, near ideal habitat. Beaver dams now exist in nearly all portions of the lower North Fork. Some beaver ponds are hundreds of feet in length. Some dams are massive and have been observed to block anadromous fish (Photograph 3, page 8).

Table 1. Assumed direct and indirect adverse impacts upon the North Fork aquatic habitat caused by the Cushman Project.

Direct Adverse Impacts	Indirect Adverse Impacts
Reduced annual and seasonal flow*	Reduced water velocities*
Infrequent but drastic changes in flow*	Reduced water depths*
Anadromous fish habitat access blocked	Reduced gravel recruitment
Total river spawning and rearing habitat area drastically reduced	Increased summer water temp*
River habitat above dams inundated	Decreased winter water temp*
	Reduced quantity of clean gravel
	Plant and tree encroachment into river
	River obstruction by beaver dams
	Altered aquatic habitat balance
	Increased human habitation near river above dams
	Increased human access downstream of lower dam causes degradation
	Reduced fall chinook, chum, coho, steelhead populations and harvest*
	Eliminated spring chinook, sockeye populations and harvest

*Impact extends downstream into the mainstem Skokomish River.

Mainstem and South Fork Habitat Status

Degradation of the mainstem and South Fork Skokomish River and respective watersheds has been more subtle and longterm than that of the North Fork. Much of the watershed area adjoining the mainstem and lower South Fork, RM 0.0 - 9.0 and 0.0 - 3.0 respectively, has undergone piecemeal clearing and conversion to agricultural and residential use. A high percentage of these river banks has been cleared and left relatively unprotected. Bank sections are eroded each year. Attempts by landowners to perform channelization or diking have resulted in further degradation.

The mainstem and lower South Fork channel beds are relatively unstable, apparently the result of seasonal runoff of greater magnitude than that which occurred prior to the watershed alterations. Increased seasonal runoff volume appears to be the result of extensive and continuous clearcut logging within the watershed. Lower valley land practices have compounded this effect. In addition, a significant portion of the upper South Fork channel appears to be unstable, and suffers from loss of streambank cover.

In pristine times all anadromous salmon and trout, except sockeye, are assumed to have utilized the South Fork. Now pink salmon are seldom observed. Chum utilization is limited to the lower valley. The mainstem Skokomish, lower South Fork and Vance Creek are important to the production of chinook, coho and chum salmon (Williams et al. 1975). Several tributaries are also heavily utilized by coho and chum salmon. Winter steelhead trout utilize the mainstem river, Vance Creek and the South Fork through most of the upper valley. A few spring chinook are believed to still migrate into the South Fork canyon where they hold in deep pools before moving to the upper river to spawn (Deschamps 1957). In addition to winter steelhead and spring chinook, fall chinook and possibly coho salmon utilize the upper South Fork. It is generally agreed that run sizes of native mainstem river and South Fork stocks are now much depressed below historic levels as a result of overharvest, introduction and increase of hatchery stocks, and watershed degradation.

Study Goals

The Cushman Dams, owned and operated by the City of Tacoma, are federally-licensed operations. The licenses are now scheduled for Federal Energy Regulatory Commission (FERC) renewal, and for consideration of any necessary modifications required by law. The Skokomish Indian Tribe has intervened in this process to secure relief from, and compensation for, the losses they have suffered due to the project's operation. The Tribe requested that several studies be performed to gather information for FERC consideration. One study would evaluate anadromous fish habitat in the Skokomish River system, and particularly in the North Fork. The Fisheries Assistance Office conducted an instream flow study on the Skokomish River system to: 1) quantify the aquatic habitat suitable for life stages of anadromous salmon and trout; and 2) determine the average monthly discharges required to optimize available fish habitat. Of greatest priority was habitat and flows of the lower North Fork. In addition North Fork and South Fork habitat would be compared.

METHODS

The incremental methodology developed by the Cooperative Instream Flow Service Group (IFG), Fort Collins, Colorado (Bovee and Milhous 1978) was used to meet study objectives. The incremental method incorporates actual stream measurements, computer hydraulic simulation, and appropriate habitat criteria to then generate predictions of suitable habitat area for a wide range of stream discharges.

Seven study areas were selected for instream sampling to represent physical habitat conditions in respective reaches of the Skokomish River (Photographs 4-10, pages 8-11). Three reaches on the lower North Fork (Figure 2), three reaches on the South Fork (Figure 3) and one reach on the mainstem were identified for representation (Appendix Table 1). Within each study area, consisting of an adjacent pool and riffle, cross-sections (transects) were selected to define physical characteristics of the channel, banks and stream hydraulics.

Data Collection

Along cross-sections perpendicular to stream flow, depth and velocity were recorded at times of relative low, intermediate, and high stream discharge. Velocity measurements were made using a top-setting wading rod and either a Price AA or Pygmy current meter. Where water depths were unwadable, a Price AA current meter was suspended over cross-section data points from a boat-mounted sounding reel. Substrate type along cross-sections was recorded at the time of low stream discharge. On all instream sampling occasions, at each study area, the river stage-ground elevation relationship was measured by instrument surveying. Physical data are available upon request from FAO, Olympia, Washington. Example tables are presented as Appendix Tables 2-4. The discharges sampled instream and used to calibrate habitat predictions are presented in Table 2.

Available Habitat Predictions

The combined data from a study area provide the basis for determination of respective stage-discharge and velocity-discharge relationships by computer simulation.

Photograph 1. Cushman Dam No. 2 at R.M. 17.3 on lower North Fork Skokomish River.

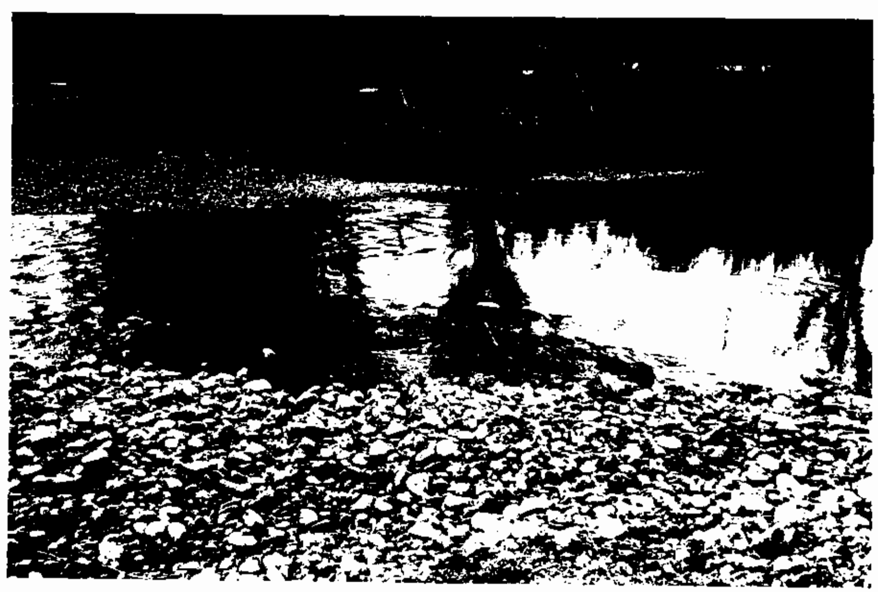
Photograph 2. North Fork Skokomish River at R.M. 29.2 upstream of Cushman Lake, and accessible to anadromous fish prior to 1926.

Photograph 3. Dense beaver dam spanning North Fork channel at about R.M. 16.8.

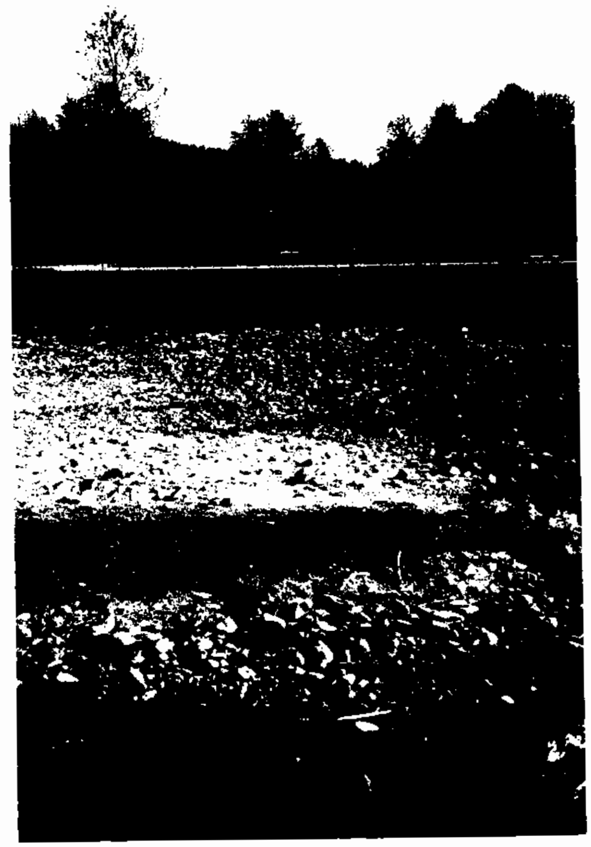
Photograph 4. View of study area N-1 looking downstream from upper transect, at time of relative low flow.

Photograph 5. View of study area N-2 looking downstream from upper transect.

Photograph 6. View across study area N-3 at upper transect. Taken at time of relative high flow.



Photograph 9. View across study area S-3 at lower transect, taken at time of relative low flow.



Photograph 10. View of study area S-4 looking upstream from lower transect, taken at time of relative low flow.

Photograph 11. View of totally dewatered channel in North Fork Skokomish River at R.M. 9.8, on August 16, 1979.

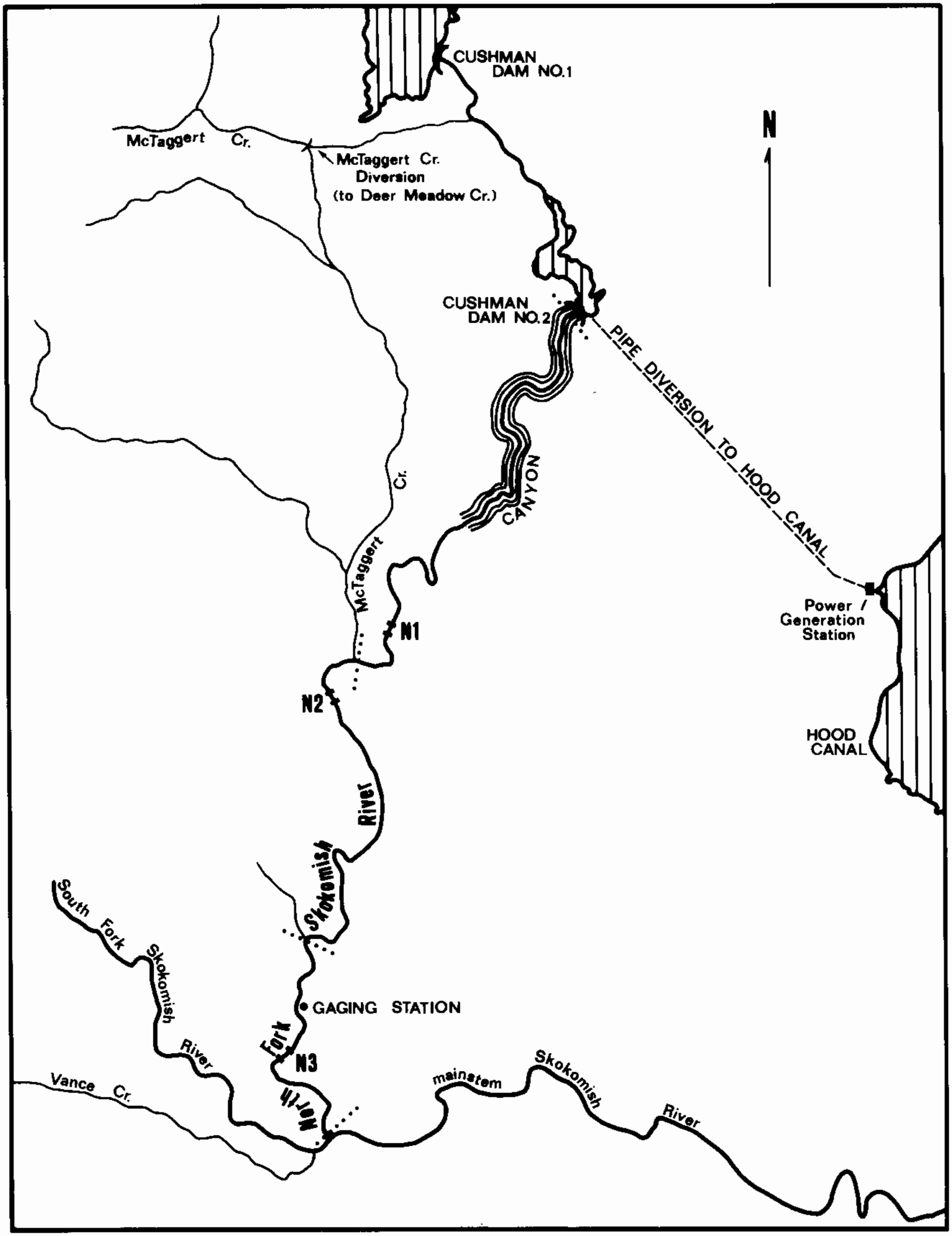


Figure 2. Lower North Fork Skokomish River study areas N1, N2, and N3 and represented river partitions (indicated by ······).

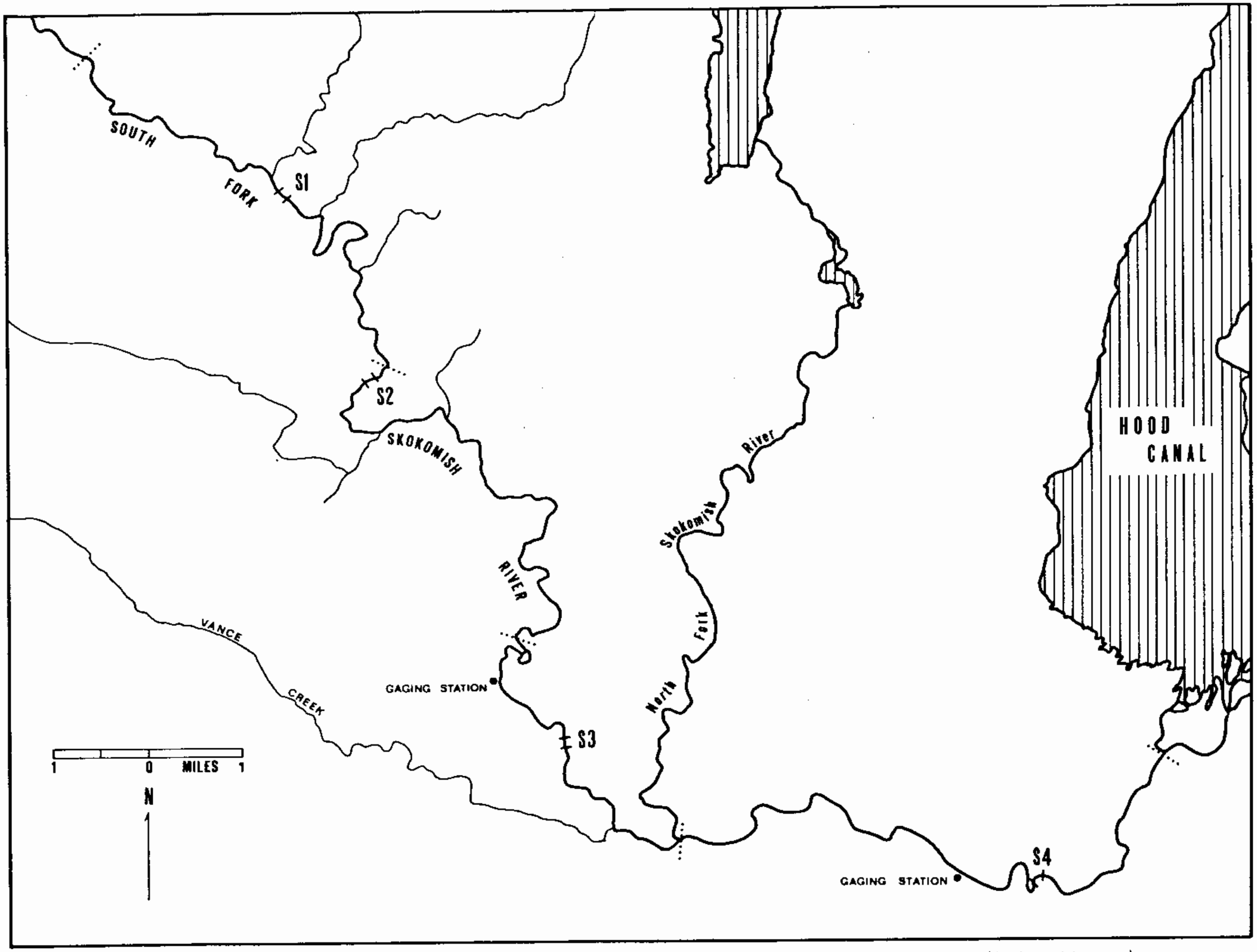


Figure 3. South Fork and mainstem Skokomish River study areas S1, S2, S3, and S4 and represented river partitions (indicated by ······).

TABLE 2. MAXIMUM, INTERMEDIATE, AND MINIMUM CALIBRATION DISCHARGES FOR ALL STUDY AREAS.

	STUDY AREA						
DISCHARGE (cfs)	N1	N2	N3	S1	S2	S3	S4
MAXIMUM (HIGH FLOW)	42.00	92.00	62.00	380.00	354.00	911.00	2879.00
INTERMEDIATE (INTER. FLOW)	14.00	45.00	39.00	238.00	231.00	194.00	658.00
MINIMUM (LOW FLOW)	7.00	13.00	10.00	111.00	140.00	124.00	347.00

A hydraulic simulation model is developed, for each study area sampled, by processing data through the IFG4 computer program. A portion of this operation consists of computer calculation of correlation coefficients (R^2) to measure statistical strength of individual models. Coefficients are determined for expected versus observed cross-sectional segment velocities, and for discharge (Q) series versus stage series. Models were derived using the stage-discharge "rating curve approach" developed by Bovee and others (Bovee and Milhous 1978).

Each hydraulic simulation model was processed by a second computer program (HABTAT) that interfaced the model with selected habitat evaluation criteria "curves" (Bovee 1978). The Bovee paper assembled much of what is known about salmonid preferences for specific levels of current velocity, water depth, and types of substrate material. The probability that a species and life stage will use specific physical conditions is plotted as a graphed line (curve). Appropriate habitat criteria curves from Bovee (1978), and additional curves developed for this study (Figures 4-7) were processed by HABTAT. Some criteria curves from Bovee (1978) are modified (Appendix Figures 1-3) to reflect preferences of western Washington anadromous stocks (Chambers et al. 1955). New criteria curves developed in this study are derived from work reported by Burner (1951), Heiser (1971) and R. Judy (1979, personal communication). The criteria curves derived from Judy are for the macroinvertebrate genera, *Stenonema* and *Acroneuria*.

The product of processing a hydraulic simulation model and appropriate habitat criteria through HABTAT is a summary table. Such a table lists predictions of weighted useable habitat area (WUA) available, as square feet, per 500 feet of stream, for each discharge processed. Thirty discharge values per study area are processed to define the peak of WUA for each species/life stage. A restriction imposed by use of the rating curve approach (Bovee and Milhous 1978) limits discharges used to 0.4 times the minimum discharge measured instream, and to 2.5 times the maximum discharge measured instream. All WUA prediction summary tables are presented as Appendix Tables 5-11. A prediction enclosed by parentheses is the optimum WUA available among the 30 discharges processed. Optimum WUA predictions and respective best discharges are presented by species and life stage, and by study area, in Tables 3 and 4.

North Fork Optimum Discharges

The need to determine one average monthly discharge that will optimize anadromous fish production requires that optimum discharge predictions from the three North Fork study areas be combined. The following procedure is applied to calculate summed proportions of suitable habitat among partitioned reaches and then determine single optimum discharges for each species/life stage: a) because all summary table predictions are expressed as suitable habitat per 500 feet of stream, a factor for

CHUM

SPAWNING

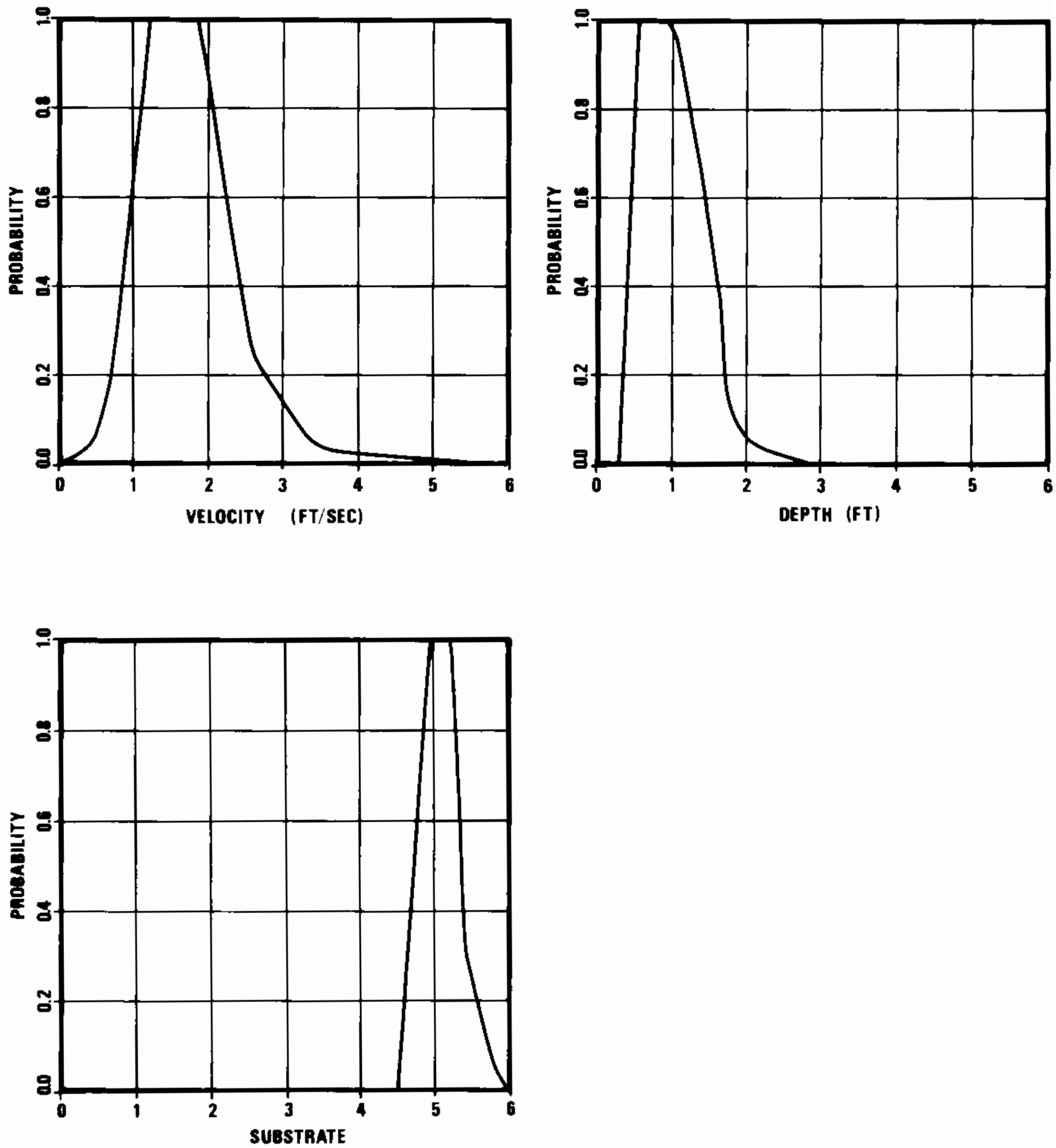


Figure 4. Chum salmon habitat criteria curves.

PINK SALMON

10700 SPAWNING FAO

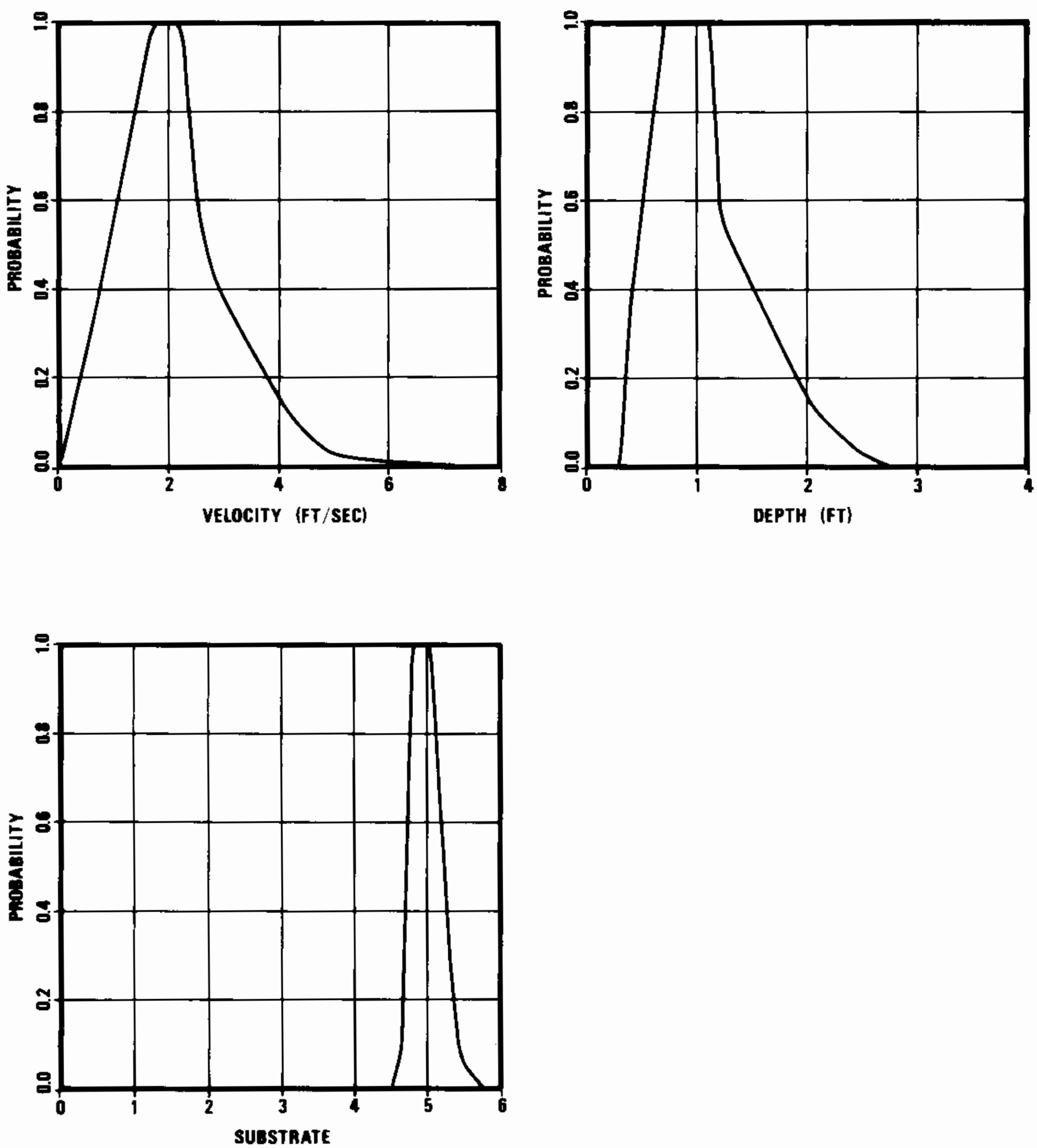


Figure 5. Pink salmon habitat criteria curves.

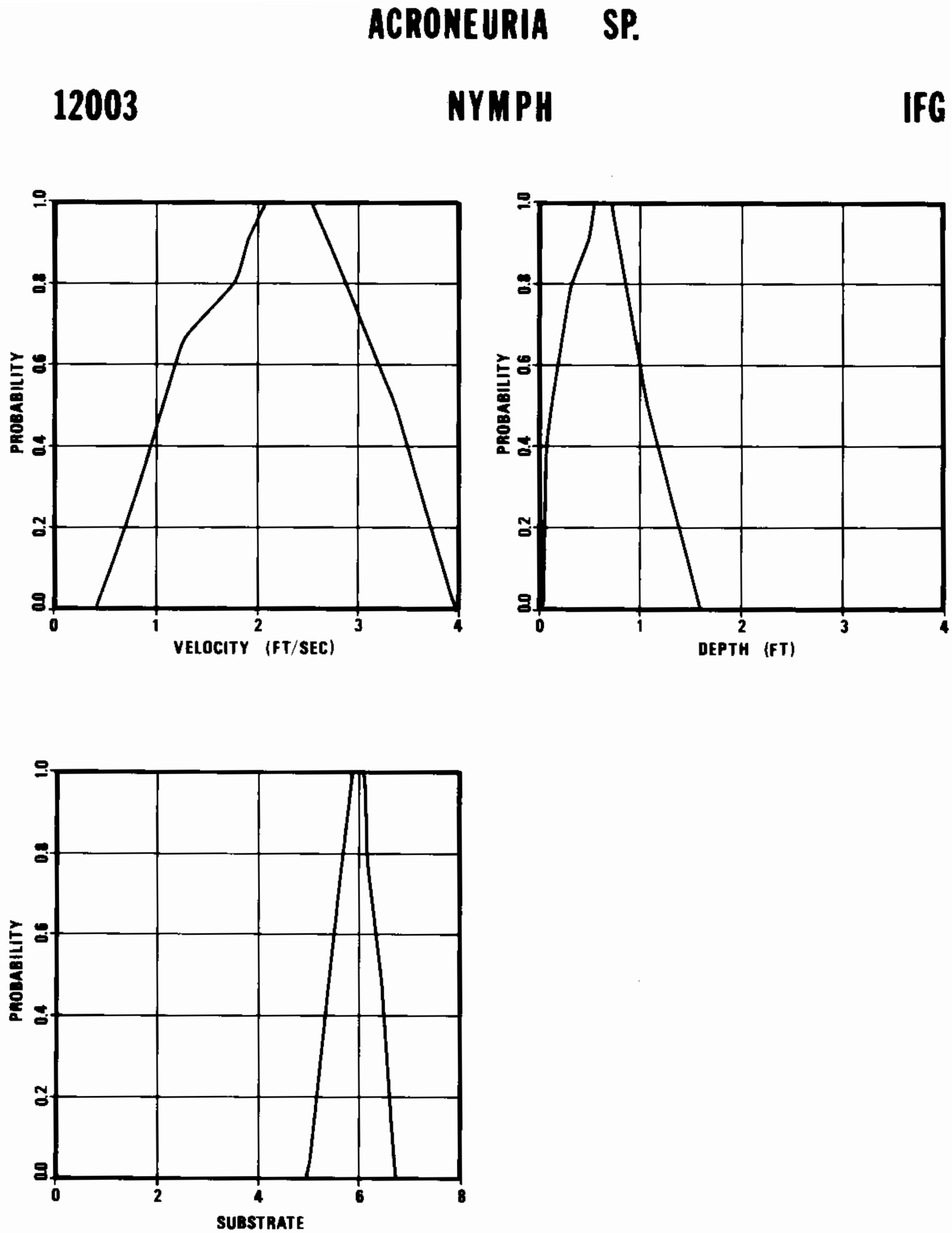


Figure 6. Acroneuria habitat criteria curves.

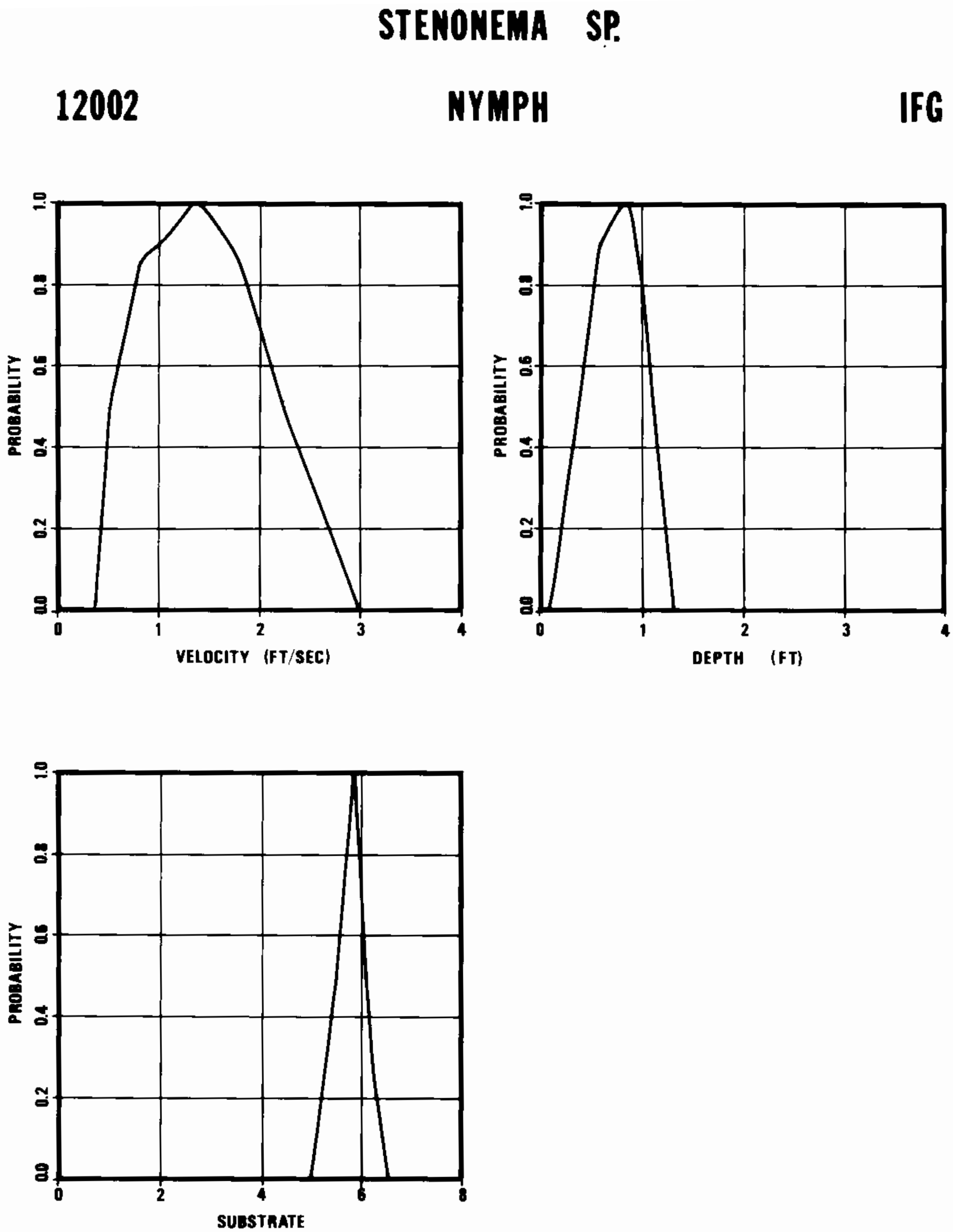


Figure 7. *Stenonema* habitat criteria curves.

TABLE 3. HABITAT MODEL PREDICTIONS FOR OPTIMUM SUITABLE HABITAT IN LOWER NORTH FORK SKOKOMISH RIVER.

STUDY AREA		COHO			CHINOOK				CHUM	PINK	SOCK.	WINTER STEELHEAD				CUTT.T.	STENO-NEMA	ACRO-NEURIA
		Spawn	Incub.	Fry	Spring Spawn	Fall Spawn	Incub.	Juv.	Spawn	Spawn	Spawn	Spawn	Incub.	Fry	Juv.	Spawn		
N1	Q (cfs)	33	33	27	70	80	33	27	33	35	33	70	37	27	33	30	25	40
	AREA, Sq. Ft., Per 500 Ft.	1136	8533	4267	1196	1123	9781	8520	2321	2280	1446	1612	11605	11905	12182	2439	2031	2522
N2	Q (cfs)	60	75	15	95	75	90	30	80	80	55	85	105	25	47	25	30	47
	AREA, Sq. Ft., Per 500 Ft.	4674	9025	3499	4567	5400	12515	6826	5217	4639	4094	4346	16280	6005	7460	2044	602	740
N3	Q (cfs)	90	62	80	60	60	62	75	65	70	70	60	65	60	62	60	45	50
	AREA, Sq. Ft., Per 500 Ft.	1221	16165	2581	2197	1534	19164	5929	2660	1961	1166	2666	19415	11309	11259	2050	4733	5798

TABLE 4. HABITAT MODEL PREDICTIONS FOR OPTIMUM SUITABLE HABITAT IN SOUTH FORK AND MAINSTEM SKOKOMISH RIVER.

STUDY AREA		COHO			CHINOOK				CHUM	PINK	WINTER STEELHEAD				CUTT.T.	STENO-NEMA	ACRO-NEURIA
		Spawn	Incub.	Fry	Spring Spawn	Fall Spawn	Incub.	Juv.	Spawn	Spawn	Spawn	Incub.	Fry	Juv.	Spawn		
S1	Q (cfs)	340	120	100	200	320	360	100	360	380	320	420	100	111	220	120	160
	AREA, Sq. Ft., Per 500 Ft.	1874	23605	1124	4593	2595	30083	5968	5089	5208	6665	41497	18123	20148	2061	9248	10532
S2	Q (cfs)	140	80	40	200	140	140	80	100	120	180	231	80	120	60	80	80
	AREA, Sq. Ft., Per 500 Ft.	1630	8846	3927	2439	2245	12969	9737	1698	1530	2502	18043	11855	14599	1313	2801	4746
S3	Q (cfs)	150	300	75	350	250	450	150	170	124	300	550	170	194	75	450	600
	AREA, Sq. Ft., Per 500 Ft.	14118	28469	12052	15039	16069	42733	22129	14953	9798	15237	63378	24828	25761	11385	4098	2985
S4	Q (cfs)	150	200	150	250	250	550	150	125	250	300	600	125	250	50	0	0
	AREA, Sq. Ft., Per 500 Ft.	10227	16162	3484	8360	11066	23655	8841	10088	9145	6975	39043	5362	10755	8914	0	0

each partitioned reach is determined by multiplying the number of stream miles in the reach by the estimated percent of the reach length free of rapids (determined by field inventory), multiplying the product by 5280 feet per mile, and then dividing by 500 feet (per surface area prediction); b) factors are then multiplied by selected surface area predictions (square feet/500 feet of stream) for species/life stages of the respective study area summary table; c) multiplication products from the three study area summary tables, i.e., N1, N2, N3, for the same predicted discharge and species/life stage are summed; d) these summations are then listed by species/life stage, compared, and discharges providing optimum suitable habitat (square feet/500 feet of stream) are determined. Table 5 represents the combined results of the preceding calculation procedure.

Calculation of summed proportions of suitable habitat for the three South Fork study areas is not performed for reasons explained in Results and Discussions.

Run Timing

Also essential to determination of mean monthly optimum discharges is detailed information on the timing of native stocks' spawning migration, as well as timing of incubation and rearing. Timing information sources include Payne (1976), J. Fenton (1978, personal communication), D. Herrera (1979, personal communication), Smoker et al. (1952), WDF (1978) and Williams et al. (1975). Run timing of pink and of sockeye salmon was conservatively reconstructed using known timing of other Puget Sound stocks of these species. Timing of spawning migrations and of spawning for salmon and steelhead trout runs in the North Fork and the remainder of the Skokomish River system are presented in Figure 8.

North Fork Critical Reach

When low discharge conditions occur on the lower North Fork, a river reach in the vicinity of RM 9.8 becomes dewatered. In anticipation of effects related to dewatering, continuous water temperature at RM 9.8 was monitored with a thermograph at the bottom of a pool. The daily high and low temperatures recorded during July, August and September, 1979 are presented graphically in Figure 9 (and tabulated in Appendix Table 12). Periodically, the river channel was observed for flow condition.

Discharge Records

The watersheds of the North Fork and South Fork are nearly equal in area. Discharge measurements made before the Cushman Project (Stimson 1943)

Table 5. Summed proportional predictions of suitable habitat and respective prediction discharges derived from summary table predictions (Appendix Tables 5-11) and calculated conversion factors (N1 = 40.55, N2 = 29.25, N3 = 15.84). Asterisks indicate discharge providing maximum suitable habitat available.

COHO	Q	Sq.Ft.
Spawning	30	120572
	33	145963
	50	182302
	*60	189802
	70	176679
	80	170166
	90	164925
	100	153514
Fry	15	171813
	20	242975
	*25	266673
	30	248792
	33	235998
	50	153667
	60	135782
	70	123220
	80	133826
	90	101253
Incubation	*33	773246
	50	732335
	60	727879
	65	703168
	75	642969

CHINOOK	Q	Sq.Ft.
Spawning (spring)	50	136185
	60	171566
	70	191906
	*80	196468
	90	194285
	100	189371

CHINOOK (cont.)	Q	Sq.Ft.
Spawning (fall)	50	190854
	60	217677
	65	221822
	70	222294
	*75	224110
	80	223828
	90	211924
Juvenile	25	578521
	*30	602229
	40	534511
	50	476609
	60	442980
	75	423314
Incubation	33	891899
	*60	930532
	80	807056
	90	750611
	65	915748

CHUM	Q	Sq.Ft.
Spawning	33	212297
	50	227822
	60	244827
	*65	246739
	70	245492
	80	238129
	90	214921

Table 5. (continued)

		Q	Sq.Ft.
PINK			
	Spawning	35	201944
		50	192816
		60	206542
		*70	212834
		80	207145
		90	196447
		65	208320
		75	211453
SOCKEYE			
	Spawning	33	132109
		50	167898
		*55	179627
		60	178942
		65	174215
		70	173527
CUTTHROAT TROUT			
	Spawning	25	126490
		*30	173994
		40	116929
		50	101762
		60	93032
		35	142354
WINTER STEELHEAD TROUT			
	Spawning	50	155740
		60	193034
		65	207115
		70	218165
		*75	219290
		80	218502
		85	215102
		90	208838

		Q	Sq.Ft.
WINTER STEELHEAD TROUT (cont.)			
	Incubation	37	1029046
		50	1054036
		*65	1075011
		70	1052513
		80	976821
		90	930125
		100	893493
		105	875960
	Fry	*25	813355
		30	797736
		50	617140
		60	593116
		70	526819
		20	751191
	Juvenile	30	834818
		*33	855319
		40	800380
		47	751693
		60	708807
		70	665161
		35	852974
ACRONEURIA		40	198267
		47	201310
		50	195043
		*45	204035
STENONEMA		20	148723
		25	165922
		30	166686
		*35	168985
		40	163193
		45	157561

Figure 8. Migration and spawning timing for native salmon and steelhead in the Skokomish River Basin. (Sources: Fenton 1979; Herrera 1979; Payne 1976; Smoker et al. 1952; WDF 1978; Williams et al. 1975).

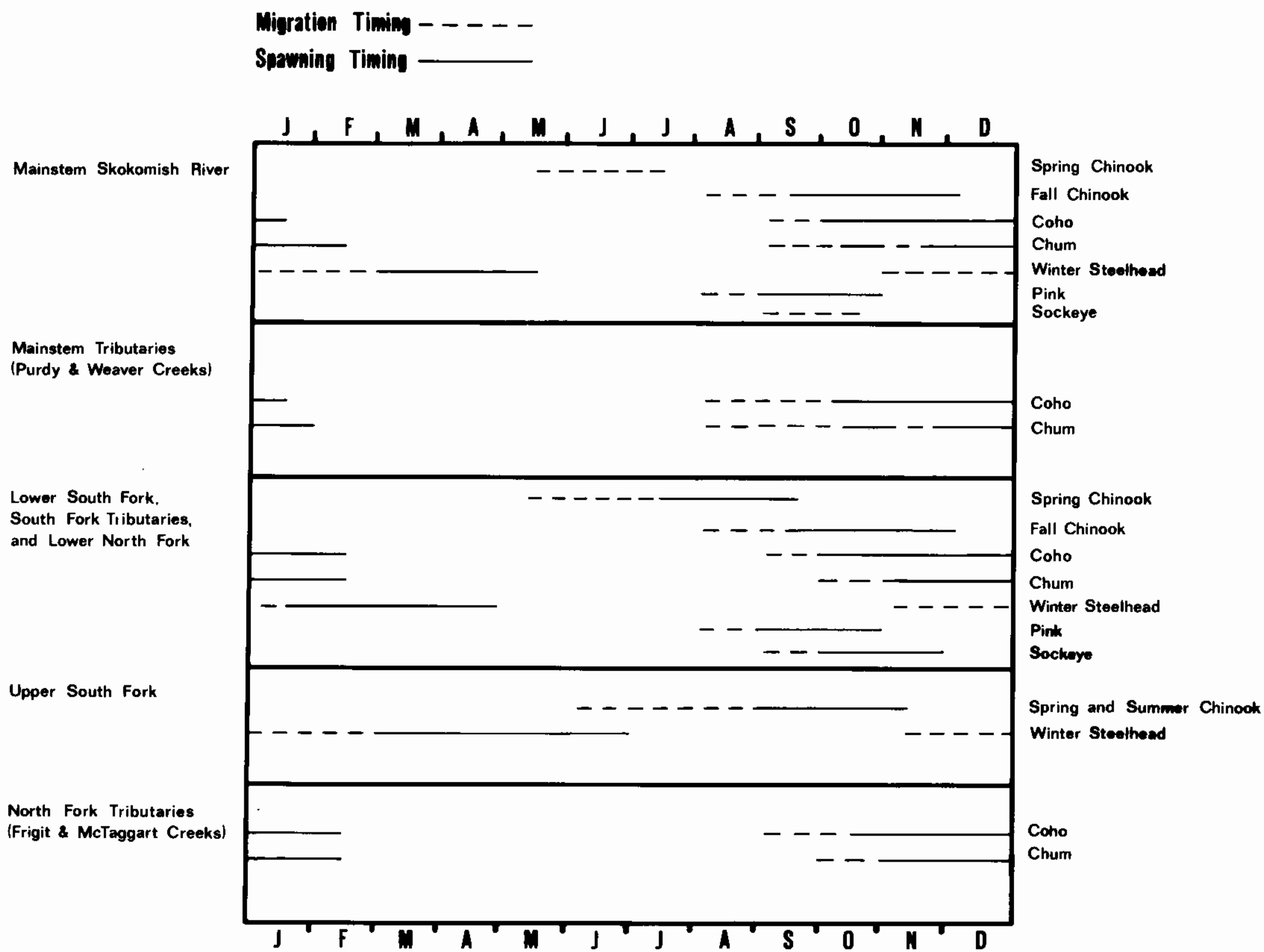
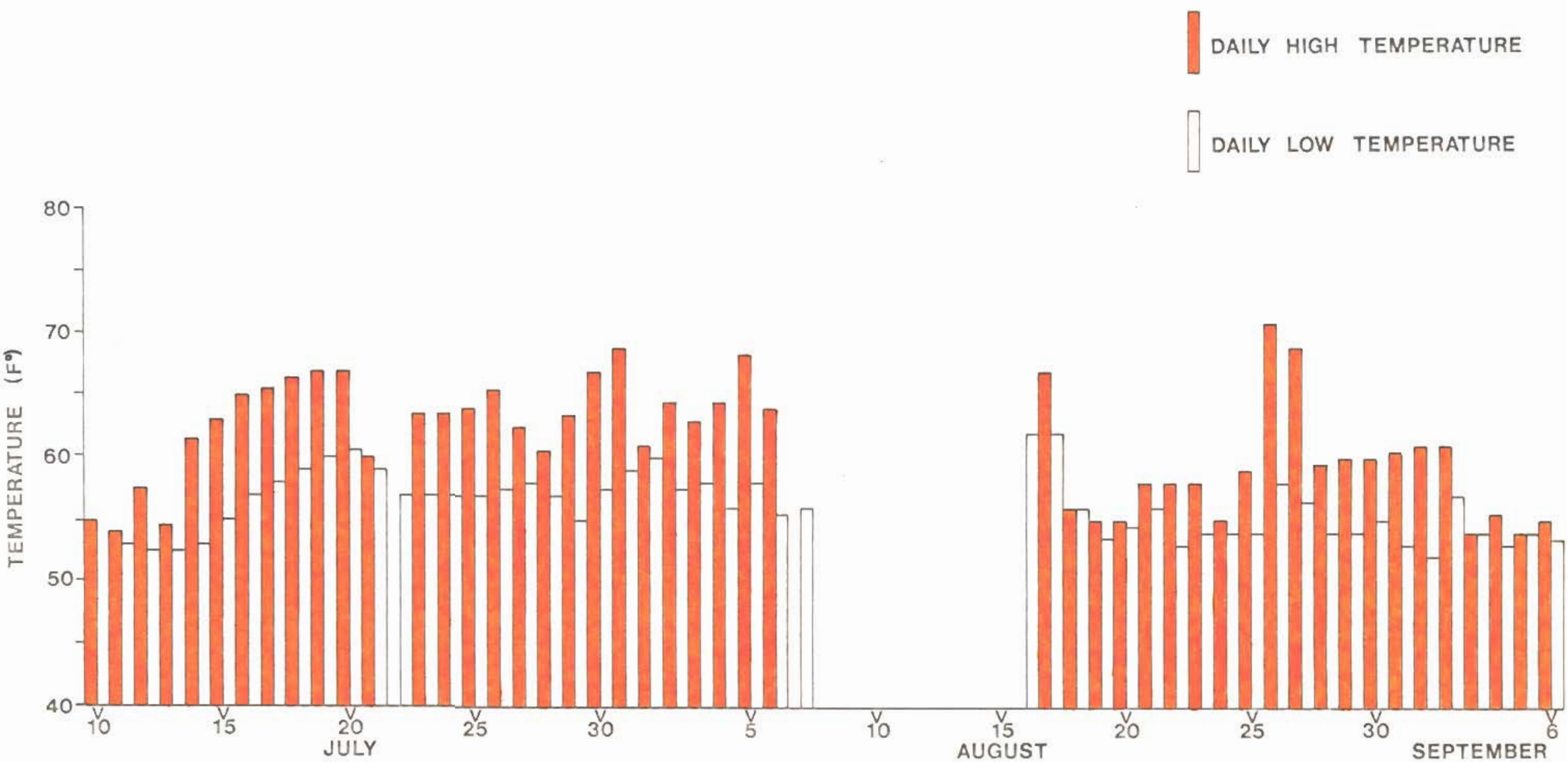


Figure 9. Daily high and low water temperatures measured in a pool at study area N-3, North Fork Skokomish River, during July, August and September, 1979.



show that the two watersheds had annual discharges of similar magnitude. Post-dam discharge is summarized in Appendix Tables 13-16, showing mean monthly discharge gaged on the upper North Fork, lower North Fork, South Fork and mainstem, respectively.

A predictive tool for determination of flow allocations (R. Milhous 1978, personal communication) is the calculation of mean monthly flows not exceeding certain year frequencies; e.g., in one out of two years 36 cfs was not exceeded during October. This type of statistic is more dependable than calculation of simple monthly means. A series of such discharge-predictive calculations developed from 1945-1974 lower North Fork gaging station records is presented in Appendix Table 17. Three statistical flow years, identified as equivalent flow years, will be used to make flow comparisons to lower North Fork species/life stage timing. Plots of 9-in-10, 1-in-2, and 1-in-10 equivalent high, median, and moderately low flow years, respectively, are presented in Figure 10. Similar equivalent flow year plots are presented and compared to appropriate South Fork and mainstem flow-timings.

RESULTS AND DISCUSSION

North Fork

IFG4 calculations of R^2 for expected versus observed cross-sectional segment velocities were as follows: study area N1, range 0.77-0.98, mean 0.87; study area N2, range 0.80-0.97, mean 0.92; and study area N3, range 0.57-1.00, mean 0.92. Calculations of R^2 for Q series versus stage series were as follows: study area N1, range 0.53-1.00, mean 0.86; study area N2, range 0.95-1.00, mean 0.98; and study area N3, range 0.97-1.00, mean 0.99.

Summed proportional predictions of optimum suitable habitat provided by specific discharges (Table 5) combined with North Fork run timing information (Figure 8) permit the construction of linear "flow timings" (Figure 11). In Figure 11, lines representing run timing of species and life stage are distributed over the range of discharges predicted to provide optimum area of suitable habitat. Duration of flow-timing for chinook incubation (C-I) is derived from review of mean lower North Fork water temperatures in winter (USGS 1965-1974, 1975-1978), and then from calculation of time to egg hatching, using 900 degree-day units (Bell 1973). Chinook juvenile (C-J) flow-timing, inclusive of the fry life stage, continues to the end of October to reflect a compromise between observed extremes of time from hatching until the onset of seaward migration (Chapman 1979). Steelhead incubation (ST-I) and fry (ST-F) duration was based on a calculation of 720 degree-day units (Bell 1973). There is no flow-timing for coho juvenile due to the lack of habitat criteria information. Where two different flow-timings occur at the same discharge

Figure 10. Month vs. discharge plot of log normal distribution of three equivalent flow years, flows not exceeded: 9 in 10 years; 1 in 2 years; and 1 in 10 years. From discharge statistics in Appendix Table 17.

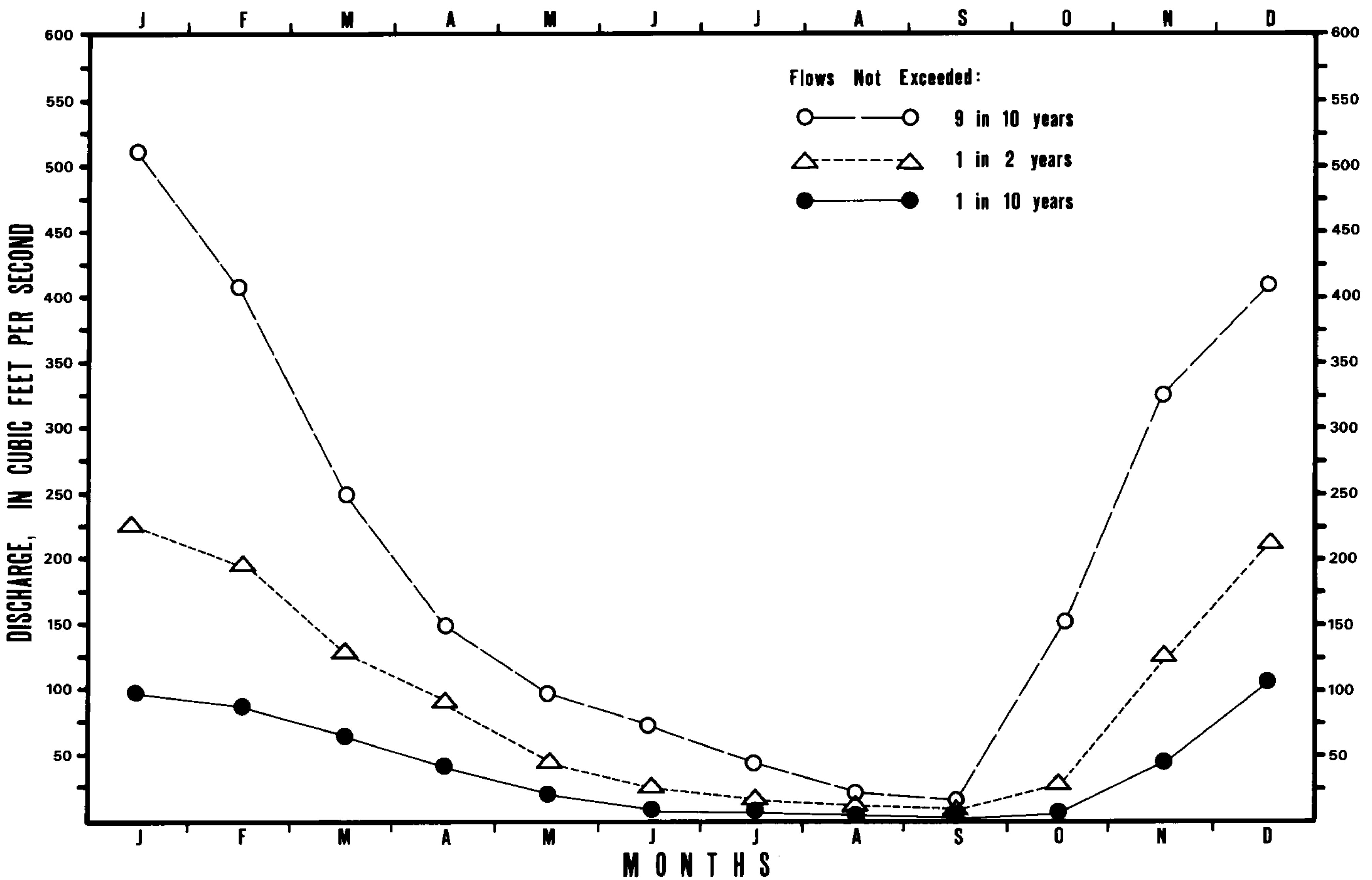
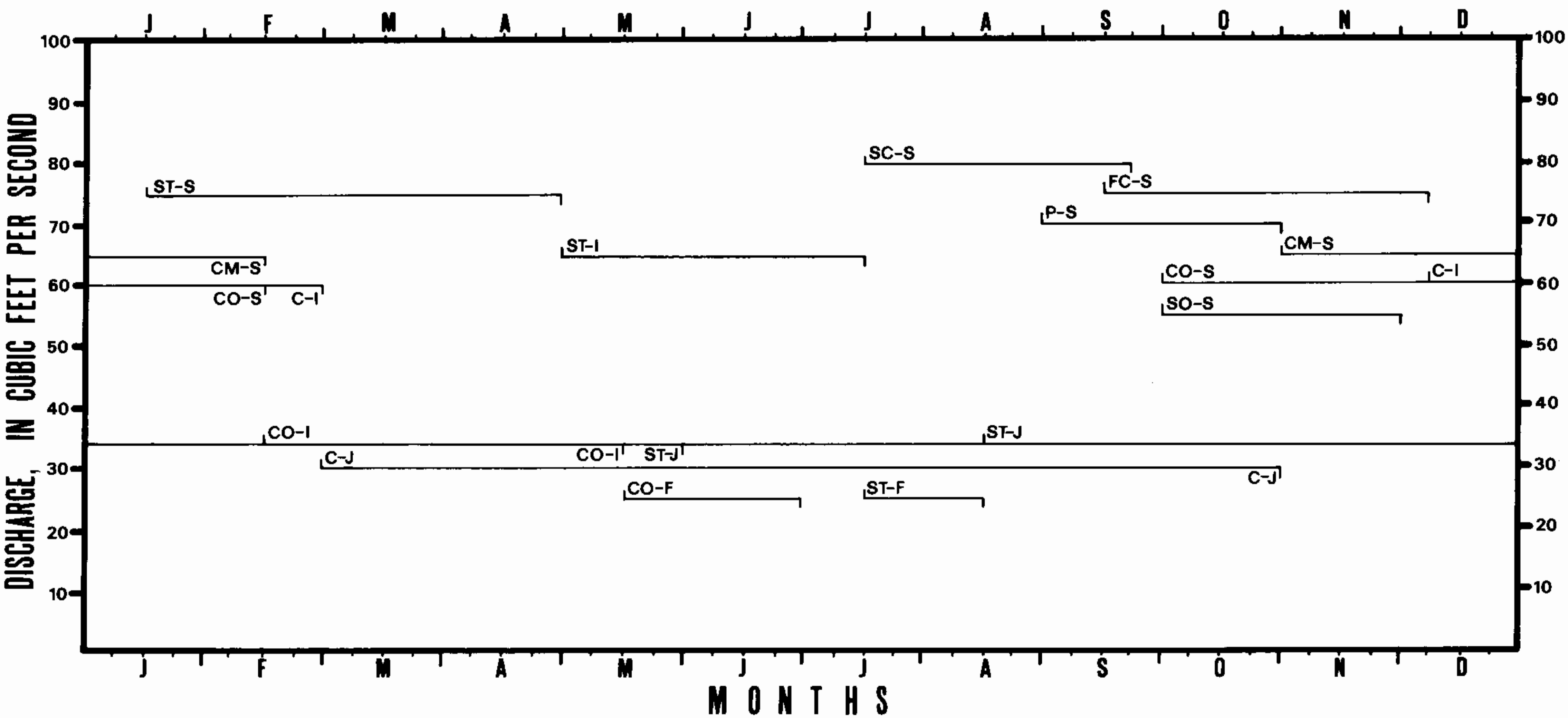


Figure 11. Lower North Fork salmon and steelhead trout life stage timings distributed by predicted discharges providing optimum suitable habitat; constructed from Figure 8 and Table 5 information. Figure coding: S=Spawning; I=Incubation; F=Fry; J=Juvenile; C=Chinook; CM=Chum; CO=Coho; FC=Fall Chinook; P=Pink; SC=Spring Chinook; SO=Sockeye; ST=Winter Steelhead.



and share some portion of a line, each flow-timing is individually begun (by a mark above line followed by coding), and ended (by a mark below line preceded by coding). Steelhead juvenile (ST-J), at 33 cfs, has a duration of approximately 21 months. All flow-timings in Figure 11 are sufficiently detailed to permit determination of semimonthly flow recommendations. Flow-timings and further discussion of cutthroat trout, *Stenonema* and *Acroneuria*, are not included in the analysis in order to reduce complexity of interpretations.

When the lower North Fork equivalent flow years, plotted by month and by discharge (Figure 10), are constructed to overlay the lower North Fork species/life stage flow-timings, also plotted by month and by discharge (Figure 11), the result, Figure 12, permits identification of equivalent flow year discharge excesses and insufficiencies for fish.

With reference to suitable habitat area information (Table 5) a number of comparisons on Figure 12 are possible. In the event of an equivalent 1-in-10 moderately low flow year many impacts upon habitat availability could be expected, including the following: from the first week of March available area for winter steelhead spawning would fall from 100% of optimum (219, 290 sq. ft. at 75 cfs) down to 25% (54,108 sq. ft.) by the end of spawning; winter steelhead available area for incubation would range from 87% of optimum (at about 30 cfs) down to less than 38% of the optimum (at 7 cfs); area available for spring chinook spawning would be, on the average, less than 2% of the optimum area available at 80 cfs; area available for fall chinook spawning would vary from under 0.7% of optimum as spawning begins, to nearly 100% of optimum as spawning ends; area available for pink spawning would begin at under 21% of optimum and end at 60% of optimum; chum spawning would begin at about 49% of optimum habitat area, then reach 100% of optimum about one month later at 75 cfs, after which discharge then increases to about 110 cfs providing 67% of optimum habitat area, and then discharge gradually falls to 88 cfs providing about 90% of optimum habitat area; for winter steelhead juveniles, that are rearing and present in all months, optimum habitat area would be available only briefly in late April and in early November, decrease to about 50% during summer low flow months, and decrease again in December to 56%. Together, these calculations show that during 1-in-10 years the monthly discharge pattern is very limiting upon anadromous fish production. This is particularly the case for species having long-term freshwater rearing requirements (R. Gerke 1978, personal communication; J. Hunter 1978, personal communication). For more than five months discharge is insufficient to provide otpimum habitat availability for any anadromous species life stage.

The equivalent 9-in-10 high flow year discharge (Figure 12) shows the greatest discharge range among the three equivalent flow years and it provides anadromous fish the least habitat stability. During approximately eight months discharge is too high to provide optimum habitat availability for any anadromous species/life stage.

Figure 12. North Fork flow-timings (Figure 11) compared with plotted monthly discharges from equivalent flow years (Figure 10).

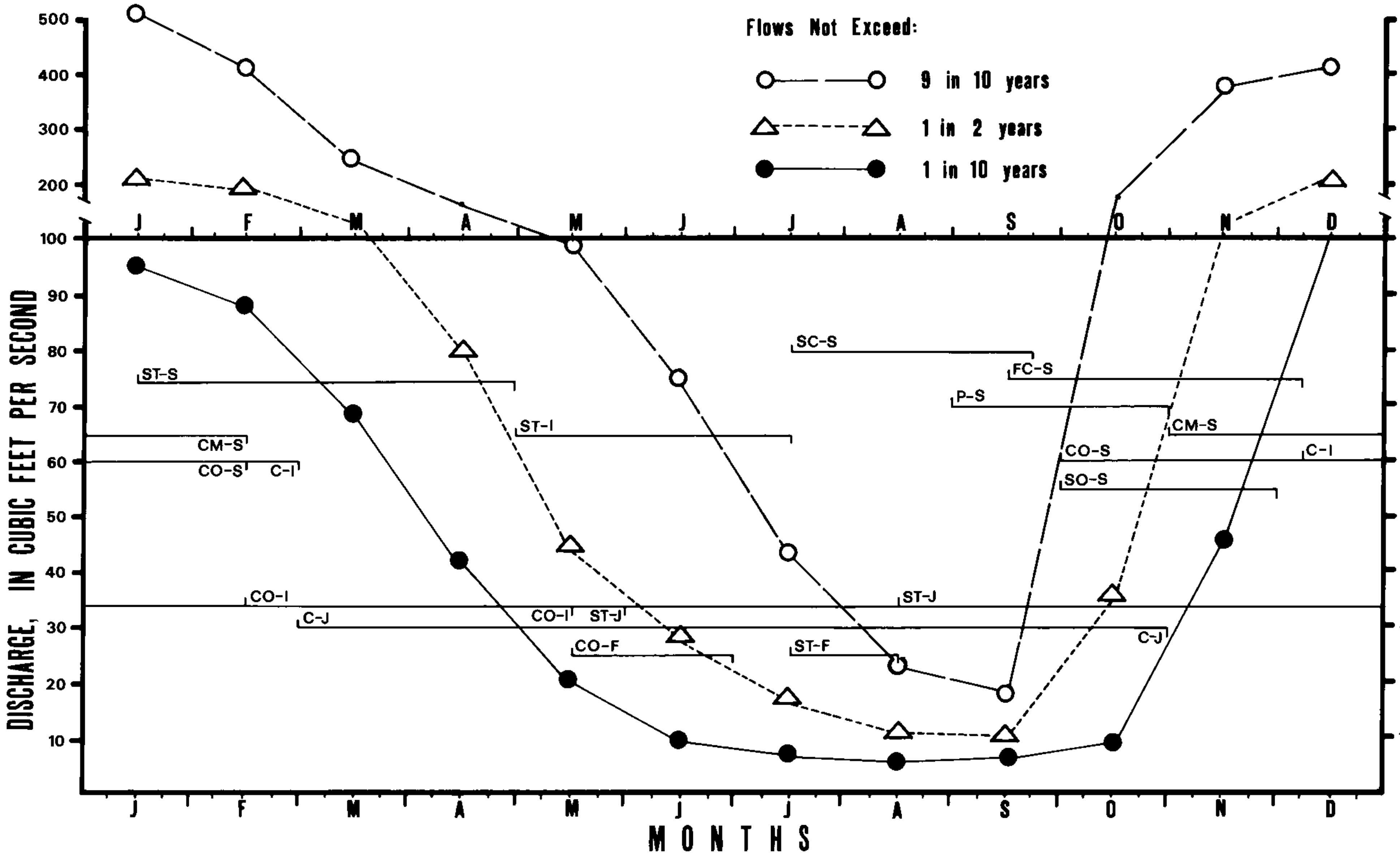


Figure 13. Alternative 1: Annual flow strategy favoring habitat enhancement of Spring Chinook (SC) and Fall Chinook (FC). (From Figure 11 information, in part).

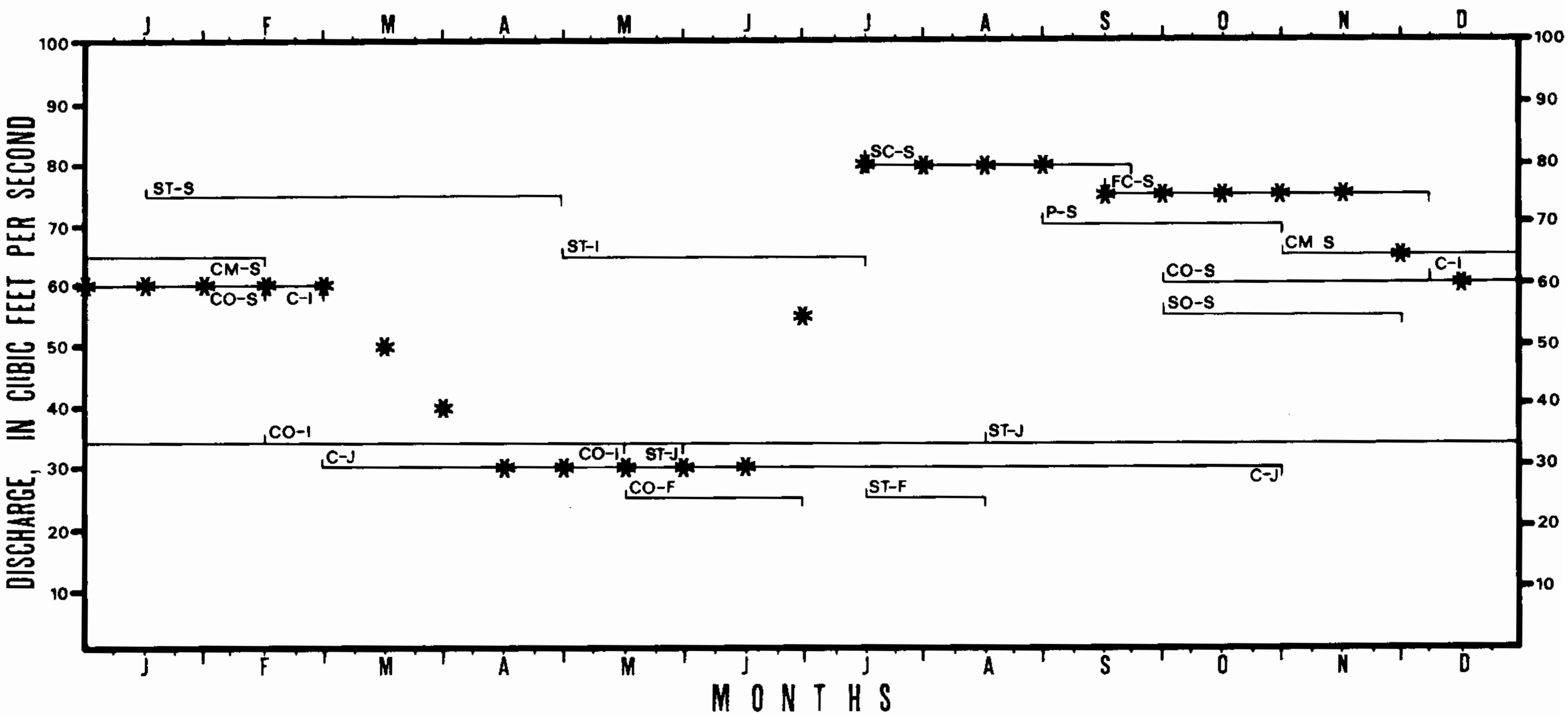


Figure 14. Alternative 2: Annual flow strategy favoring combined habitat enhancement of Fall Chinook (FC), Chum (CM), and Coho (CO) Salmon. (From Figure 11 information, in part).

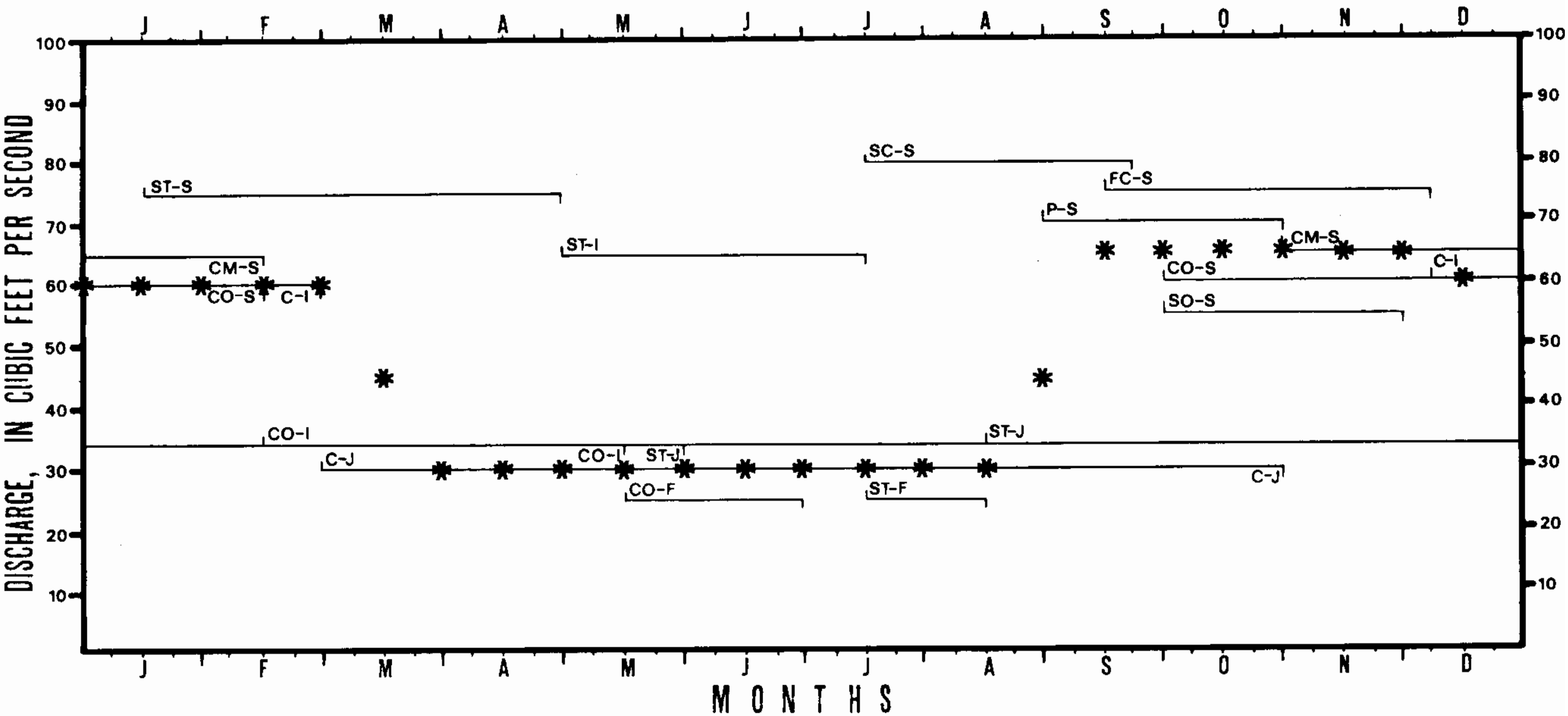


Figure 15. Alternative 3: Annual flow strategy favoring combined habitat enhancement of Fall Chinook (FC) and Coho (CO) Salmon, and Winter Steelhead Trout (ST). (From Figure 11 information, in part).

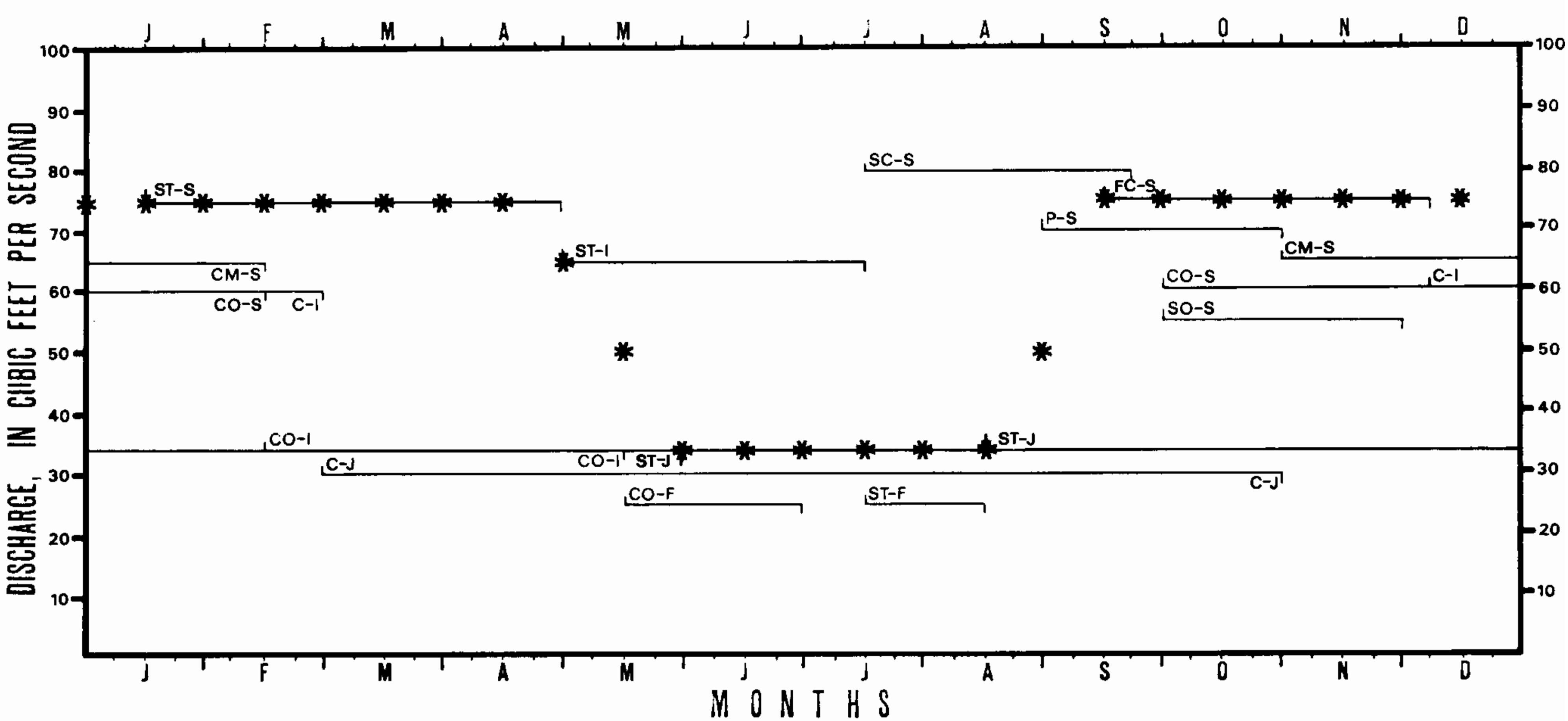
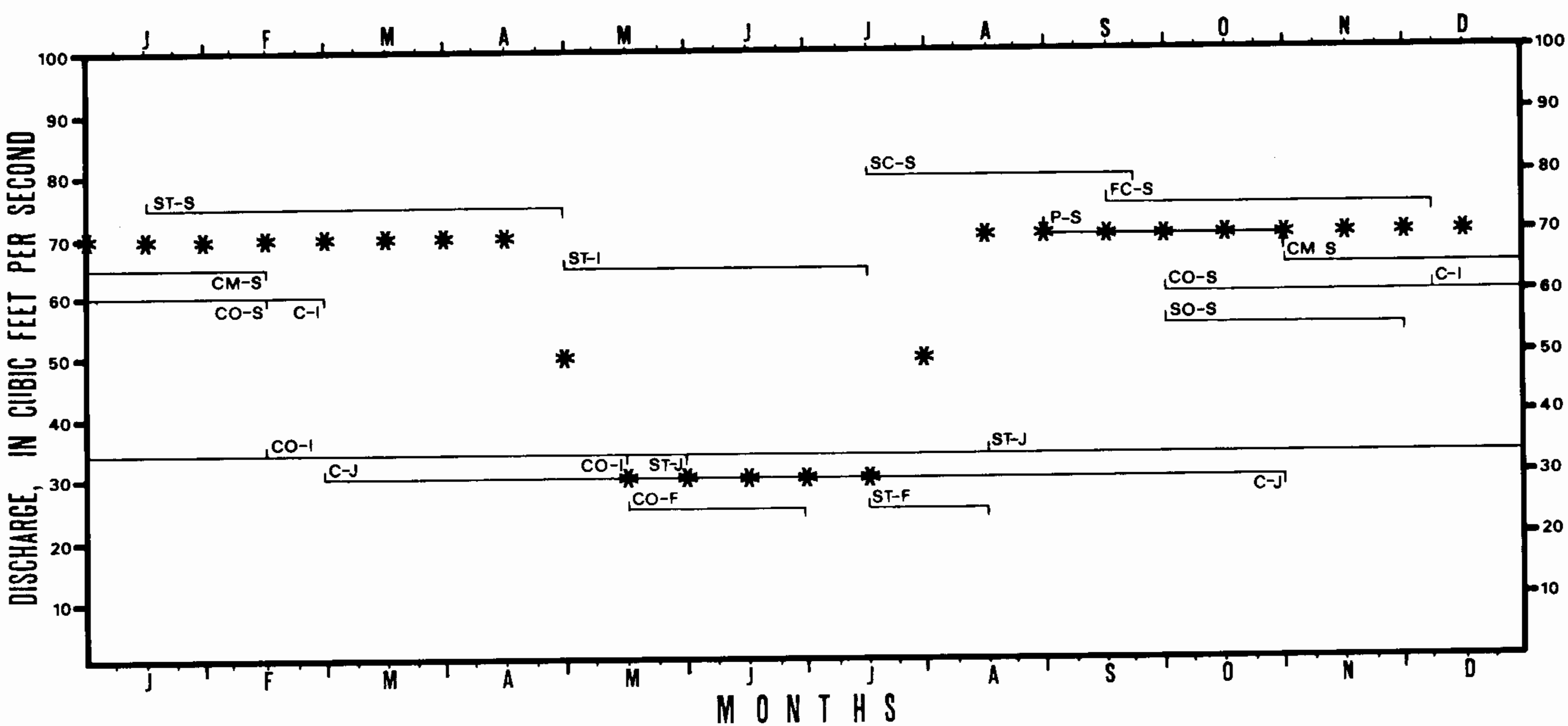


Figure 16. Alternative 4: Annual flow strategy favoring combined habitat enhancement of all species spawning and rearing (fry and juvenile stages). (From Figure 11 information, in part).



Tables 6, 7 and 8 each present the semimonthly discharges (cfs) required under the five alternative strategies and the respective water releases (cfs) needed to satisfy the requirement. Tables 6, 7 and 8 water releases are those that would be required by the five alternatives in the event of an equivalent median, moderately low, or high flow year, respectively. The entry of "E" in Tables 6, 7 and 8 indicates that the equivalent year discharge either equals or exceeds the respective discharge required by an alternative strategy. The proportion of an equivalent flow year equaling or exceeding alternative strategy requirements is least during a moderately low flow year, and is most during a high flow year. Efficacy of a given alternative strategy would be least during an equivalent high flow year.

The benefits for the fisheries (increased habitat area) that are represented by water releases in Tables 6, 7 and 8 will vary with species and life stages, date, and relative flow year. Benefits, expressed as total area (sq. ft.) of available suitable habitat in the combined lower North Fork, can be demonstrated by comparing a given alternative with a given equivalent flow year. For the mean monthly discharges of an equivalent 1-in-2 flow year (Appendix Table 17) and alternative 3 discharge requirements (Table 6), the period of water release begins on May 15 and ends October 31. Calculations show that during this period area available for C-J (optimum 602,229 sq. ft.) would either be increased or decreased by the effects of water release as follows: May 15-31, 24,600 sq. ft. decrease; June 1-14, no release; June 15-30, 19,200 sq. ft. decrease; July 1-14, 43,000 sq. ft. increase: July 15-31, 130,900 sq. ft. increase; August 1-14, 191,500 sq. ft. increase; August 15-31, 278,900 sq. ft. increase; and September 1-14, 173,700 sq. ft. increase. Beginning September 15, alternative 3 favors C-S. Available area for FC-S (optimum 224,100 sq. ft.) would be affected as follows: September 15-30, 222,500 sq. ft. increase; October 1-14, 186,700 sq. ft. increase; and October 15-31, 106,900 sq. ft. increase.

During the same period calculations show area available for ST-J (optimum, 855,319 sq. ft.) would be affected approximately as follows: May 15-31, 30,900 sq. ft. decrease; June 1-14, no release; June 15-30, 41,800 sq. ft. increase; July 1-14, 112,300 sq. ft. increase; July 15-31, 249,500 sq. ft. increase; August 1-14, 358,300 sq. ft. increase; August 15-31, 447,400 sq. ft. increase; September 1-14, 325,000 sq. ft. increase; September 15-30, 264,000 sq. ft. increase; October 1-14, 102,100 sq. ft. decrease; and October 15-31, 202,800 sq. ft. decrease.

The preceding examples demonstrate that available habitat is very substantially increased, overall, by the effects of alternative 3. They also show that lower North Fork habitat availability has been at levels well below optimum since dam construction in 1930.

A factor that must be considered in determining water releases to optimize lower river habitat area is the effect of such releases on the

Figure 17. Alternative 5: Annual flow strategy favoring combined habitat enhancement of Spring Chinook (SC), Fall Chinook (FC), and Winter Steelhead, for spawning and incubation. (From Figure 11 information, in part).

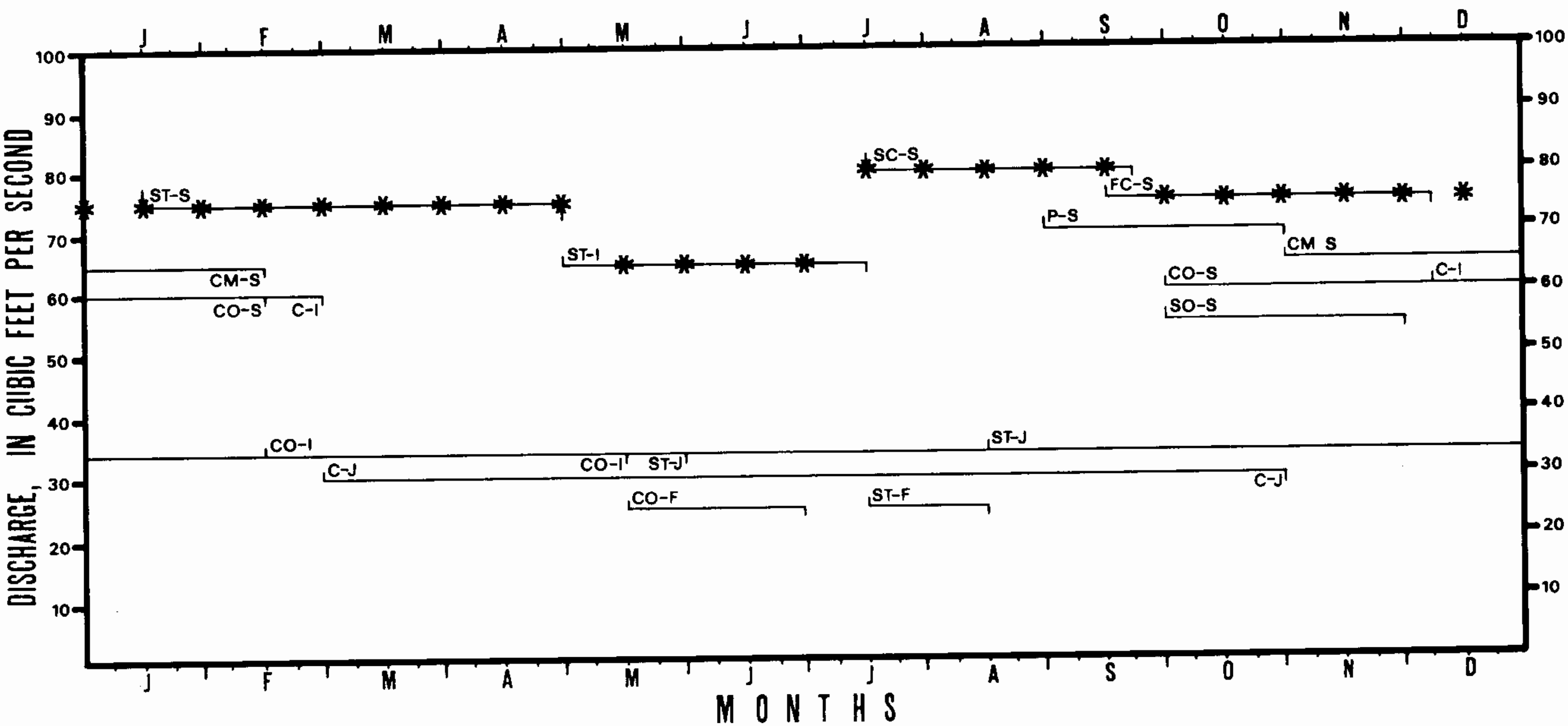


Table 6. In the event of an equivalent 1 in 2 median flow year, values (cfs) for semimonthly flows to enhance habitat availability for selected North Fork fish species/life stages, and respective semimonthly dam releases (cfs) required to satisfy enhancement. Note: "E" indicates river base flow meets or exceeds enhancement flow. Semimonthly values fall either on the 1st day of the respective month (1st value under a month) or on the 15th day of the month.

FLOW STRATEGY ALTERNATIVES	MONTHS																							
REGIME OF DAM RELEASES (SPILLS) TO SATISFY FLOW STRATEGY	J		F		M		A		M		J		J		A		S		O		N		D	
Alternative 1: Flows favoring spring chinook and fall chinook salmon (from Figure 11)	60	60	60	60	60	50	40	30	30	30	30	30	55	80	80	80	80	75	75	75	75	75	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	30	60	65	70	70	65	50	40	E	E	E	E
Alternative 2: Flows favoring fall chinook, chum, and coho salmon (from Figure 12)	60	60	60	60	60	45	30	30	30	30	30	30	30	30	30	30	45	65	65	65	65	65	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	5	15	15	20	35	55	40	30	E	E	E	E
Alternative 3: Flows favoring fall chinook and coho salmon, and winter steelhead trout (from Figure 13)	75	75	75	75	75	75	75	75	65	50	33	33	33	33	33	33	50	75	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	E	E	E	E	5	E	5	10	15	20	20	40	65	50	40	E	E	E	E
Alternative 4: Flows favoring all species' spawning and rearing (from Figure 14)	70	70	70	70	70	70	70	70	50	30	30	30	30	30	50	70	70	70	70	70	70	70	70	70
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	5	15	35	60	60	60	45	35	E	E	E	E
Alternative 5: Flows favoring spring and fall chinook salmon and winter steelhead trout, for spawning and incubation (from Figure 15)	75	75	75	75	75	75	75	75	75	65	65	65	65	80	80	80	80	80	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	E	E	E	10	20	30	35	40	65	65	70	70	70	50	40	E	E	E	E

Table 7. In the event of an equivalent 1 in 10 moderately low flow year, values (cfs) for semimonthly flows to enhance habitat availability for selected North Fork fish species/life stages, and respective semimonthly dam releases (cfs) required to satisfy enhancement. Note: "E" indicates river base flow meets or exceeds enhancement flow. Semimonthly values fall either on the 1st day of the respective month (1st value under a month) or on the 15th day of the month.

FLOW STRATEGY ALTERNATIVES REGIME OF DAM RELEASES (SPILLS) TO SATISFY FLOW STRATEGY	J		F		M		A		M		J		J		A		S		O		N		D	
Alternative 1: Flows favoring spring chinook and fall chinook salmon (from Figure 11)	60	60	60	60	60	50	40	30	30	30	30	30	55	80	80	80	80	75	75	75	75	75	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	10	15	20	45	75	75	75	75	70	70	65	50	30	E	E
Alternative 2: Flows favoring fall chinook, chum, and coho salmon (from Figure 12)	60	60	60	60	60	45	30	30	30	30	30	30	30	30	30	30	45	65	65	65	65	65	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	10	15	20	20	25	25	25	40	60	60	55	40	20	E	E
Alternative 3: Flows favoring fall chinook and coho salmon, and winter steelhead trout (from Figure 13)	75	75	75	75	75	75	75	75	65	50	35	35	35	35	35	35	50	75	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	5	20	30	35	30	20	25	25	25	25	30	45	70	70	65	50	30	E	E
Alternative 4: Flows favoring all species' spawning and rearing (from Figure 14)	70	70	70	70	70	70	70	70	50	30	30	30	30	30	50	70	70	70	70	70	70	70	70	70
Required dam releases	E	E	E	E	E	E	15	25	20	10	15	20	20	25	45	65	65	65	65	60	45	25	E	E
Alternative 5: Flows favoring spring and fall chinook salmon and winter steelhead trout, for spawning and incubation (from Figure 15)	75	75	75	75	75	75	75	75	75	65	65	65	65	80	80	80	80	80	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	5	20	30	45	45	50	55	55	75	75	75	75	75	70	65	50	30	E	E

Table 8. In the event of an equivalent 9 in 10 high flow year, values (cfs) for semimonthly flows to enhance habitat availability for selected North Fork fish species/life stages, and respective semimonthly dam releases (cfs) required to satisfy enhancement. Note: "E" indicates river base flow meets or exceeds enhancement flow. Semimonthly values fall either on the 1st day of the respective month (1st value under a month) or on the 15th day of the month.

FLOW STRATEGY ALTERNATIVES / REGIME OF DAM RELEASES (SPILLS) TO SATISFY FLOW STRATEGY	MONTHS: J		F		M		A		M		J		J		A		S		O		N		D	
Alternative 1: flows favoring spring chinook and fall chinook salmon (from Figure 11)	60	60	60	60	60	50	40	30	30	30	30	30	55	80	80	80	80	75	75	75	75	75	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	E	35	45	55	60	55	E	E	E	E	E	E
Alternative 2: Flows favoring fall chinook, chum, and coho salmon (from Figure 12)	60	60	60	60	60	45	30	30	30	30	30	30	30	30	30	30	45	65	65	65	65	65	65	60
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	5	25	45	E	E	E	E	E	E
Alternative 3: Flows favoring fall chinook and coho salmon, and winter steelhead trout (from Figure 13)	75	75	75	75	75	75	75	75	65	50	35	35	35	35	35	35	50	75	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	10	30	55	E	E	E	E	E	E
Alternative 4: Flows favoring all species' spawning and rearing (from Figure 14)	70	70	70	70	70	70	70	70	50	30	30	30	30	30	50	70	70	70	70	70	70	70	70	70
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	E	E	15	45	50	50	E	E	E	E	E	E
Alternative 5: Flows favoring spring and fall chinook salmon and winter steelhead trout, for spawning and incubation (from Figure 15)	75	75	75	75	75	75	75	75	75	65	65	65	65	80	80	80	80	80	75	75	75	75	75	75
Required dam releases	E	E	E	E	E	E	E	E	E	E	E	E	5	35	45	55	60	60	E	E	E	E	E	E

upper reach (RM 13.3-17.3). McTaggert Creek contributes significantly to the total North Fork discharge downstream of RM 13.3. "Required dam release" information in Tables 6, 7 and 8 show that during many months it would be preferable to reduce lower river discharge. However, if accomplished by reduced water release at the dam, the upper reach could then have less than optimal discharge for habitat needs.

Optimum discharge for 12 of 17 species' life stages at N1 ranges between 25-35 cfs (Table 3). Flow-timings are presented in Figure 18. Optimum area of suitable habitat for C-J, CO-F and ST-F is available at 25 cfs. The establishment of a minimum release discharge of 25 cfs would insure relative optimum habitat availability. Release discharges greater than 25 cfs would be determined by requirements of the chosen alternative for the combined lower North Fork (Tables 6, 7 and 8).

It is important to recognize that all of the above optimum discharge recommendations are based upon predictions from a river channel having characteristics much altered from those of the pre-dam channel. The pre-dam channel was considerably larger. Optimum discharges then were also much larger.

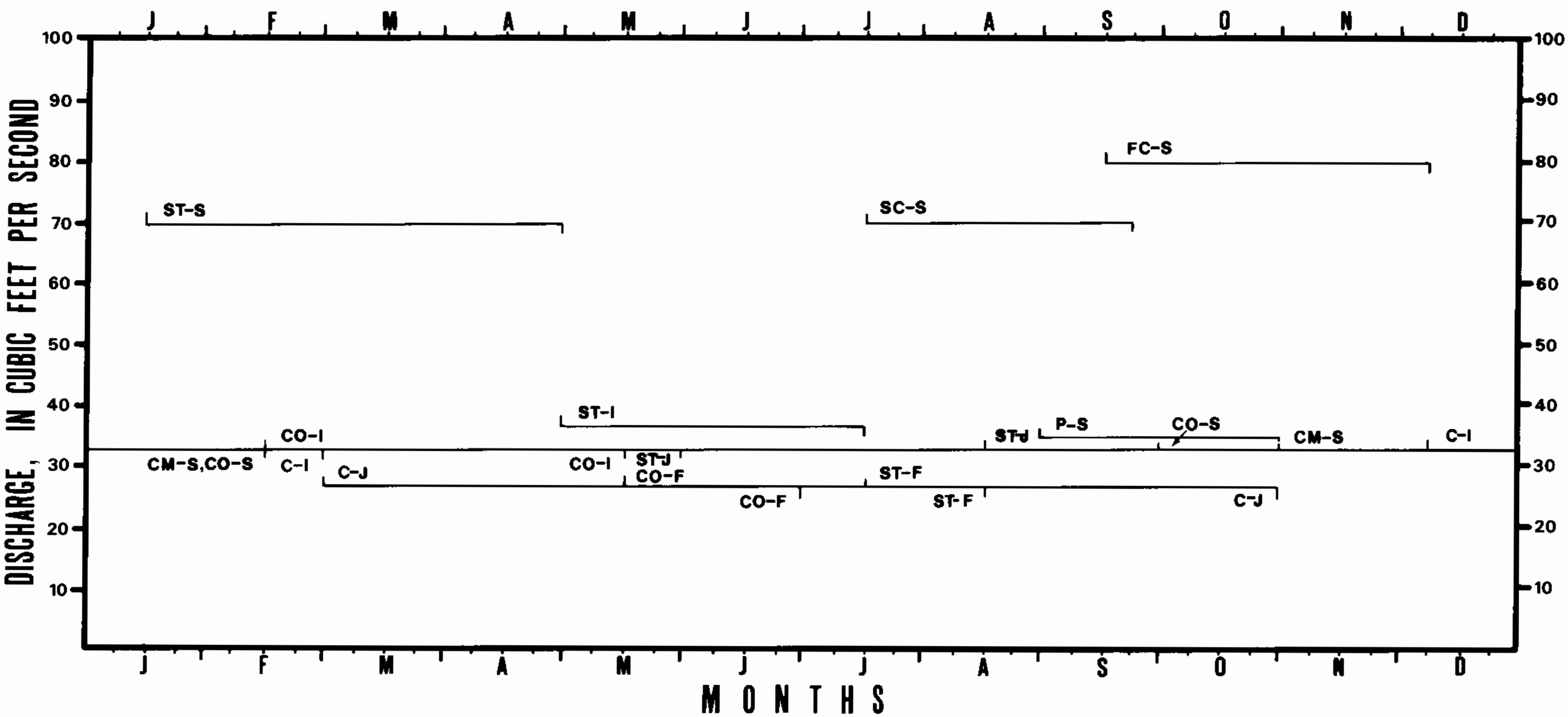
North Fork Critical Reach

The daily high and low temperatures recorded in the pool at RM 9.8 are presented in Appendix Table 12. Figure 8 timing information indicates that during the sampled period spawning spring chinook and pink salmon, rearing winter steelhead trout, and rearing chinook (and coho) salmon would ideally be present. Had these fish, in fact, been present, Bell's (1973) temperature recommendations indicate: a) for the duration of at least seven 24-hour periods in July and five 24-hour periods in August water temperature exceeded the optimum preferred range for chinook, silver and pink salmon; and b) for the duration of at least fifteen 24-hour periods in July, ten 24-hour periods in August, and one 24-hour period in early September water temperature exceeded the upper limit for migrating spring chinook, and exceeded the upper threshold for spawning spring chinook.

In August, 1979, I observed 660 feet of dewatered channel near RM 9.8 (Photograph 11, page 12). Apparently this reach is dewatered at a discharge of just less than 10 cfs. Channel dewatering reduces anadromous fish habitat, reduces abundance of prey organisms, and is a total barrier to fish migration. All anadromous fish that utilize the lower North Fork are adversely impacted by dewatering in this critical reach.

The hydraulic relationship between discharge gaged at USGS gaging station No. 1205950000 and discharge providing adequate flow conditions for spawning migrations, smolt migrations, and maintenance of prey organisms in the critical reach should be determined. During the low flow season

Figure 18. Flow-Timings for river reach from mouth of McTaggert Creek (R.M. 13.3) upstream to dam. From N-1 summary table predictions of optimum habitat (Appendix Table 5) and from Figure 8.



this information should then be used to correct the gaging station guidance for required water releases at the dam. By this procedure the significant limitations upon the anadromous fishery caused by channel dewatering can be prevented.

Fishery resource managers assigned to initiate actions to bring about restoration of lower North Fork native anadromous fish stocks have the opportunity to select one of the above alternative strategies, or one of their own design. The discharges providing optimum habitat area (Table 5) and the flows favoring selected species within each of the five alternatives (Tables 6, 7 and 8) form the information base to manage water releases. However, all discharge information presented above determined from compared equivalent flow year statistics, e.g. "required dam releases" (Tables 6, 7 and 8), are presented only as examples of most likely discharge relationships. Equivalent flow year-related examples do demonstrate what the expected range of releases would be during a typical 10-year period. Actual water releases must be based on *existing* water volumes in the river channel at USGS gaging station No. 1205950000.

The restoration of enhancement flows in the lower North Fork would logically occur as long as the Cushman Project exists. Modifications of Cushman Dam No. 2 would be required to incorporate equipment capable of accurately controlling release discharge to within 5 cfs. Cost in dollars of future lost water that could be used to generate hydroelectric power has been addressed by Morrison-Maierle, Inc. (1979). These and other anticipated impacts are listed in Table 9.

South Fork

IFG4 calculations of R^2 for expected versus observed cross-sectional segment velocities were as follows: study area S1, range 0.70-0.99, mean 0.91; study area S2, range 0.65-0.94, mean 0.85; and study area S3, range 0.95-0.99, mean 0.97. Calculations of R^2 for Q series versus stage series were as follows: study area S1, range 0.96-1.00, mean 0.99; study area S2, range 0.98-1.00, mean 0.99; and study area S3, range 0.99-1.00, mean 1.00.

Study area S3 WUA predictions for salmon and steelhead trout are all greater than respective predictions for either S1 or S2 (Table 4). Spawning ground surveys (Egan 1978, 1979) indicate that most spawning salmon in the South Fork utilize the lower partitioned reach, represented by S3. This preference can be explained by the greater habitat availability in the lower river, as indicated by WUA predictions, and the minimal distance for spawning migration.

Because the South Fork is not diverted or impounded and flows are not controlled, it is not useful to determine single optimum discharges for

Table 9. Assumed beneficial and adverse impacts to result from restoration of enhancement flows originating at Cushman Dam No. 2.

IMMEDIATE BENEFICIAL IMPACTS	EVENTUAL BENEFICIAL IMPACTS	ADVERSE IMPACTS
Restoration of flows that provide maximum suitable habitat area and conditions for preferred species	Increased production of fall chinook, chum, coho and winter steelhead	Some reduction in hydroelectric power generation by Tacoma City Light
Restoration of summer flows sufficient to prevent channel dewatering and provide suitable conditions for fish migrations, rearing and spawning	Possible reestablishment of spring chinook	Cost of constructing repairs and modifications to lower dam for water release
Improve water temperature conditions and streambed substrate conditions	Increased tribal and sport fisheries	Revised dam operation cost
Reduced occurrence of and damage due to drastic alterations of spill from the lower dam	Partial restoration of tribal cultural opportunities extant prior to dam construction	Cost of modification of lower gaging station to provide telemetry capability, and cost of continued operation, in part
	Strengthening of local economy	Cost of proposed study to determine flow requirements in critical reach (RM 9.8)
	Partial restoration of river habitat and aesthetics to pre-dam character	
	Partial reversal of trend in riparian encroachment upon the river channel	
	Reduced opportunities for beaver to construct barrier-causing dams	

the combined partitioned reaches. Flow-timings for the lower South Fork (represented by S3) are presented in Figure 19. Figure 19 compares flow-timings to the plot of an equivalent 1-in-2 median flow year (determined from South Fork gaging station No. 1206050000 records). The comparison indicates no species' spawning success is favored by discharges of an equivalent median flow year. From mid-October to mid-June these discharges greatly exceed predicted optimum discharges, thus greatly reducing available WUA. From mid-June to mid-October median discharge only briefly favors optimum WUA for fall chinook. Despite the abundance of spawning substrate it appears that lower South Fork excessive discharges nullify the optimum potential.

North Fork and South Fork Comparison

Comparison of North Fork and South Fork anadromous salmonid habitat is important because the extent of North Fork habitat loss should be determined to support or refute such claims brought before the FERC. This comparison of habitat abundance before Cushman Project construction is valid because the two rivers drain adjacent watersheds, they have comparable watershed size, they contained comparable total miles of accessible habitat, and the two mainstems had comparable mean discharge rates.

The respective predictions of habitat WUA per 500 lineal feet of stream for the two rivers provide a reasonable yardstick for comparison of an unmodified river, the South Fork, and the modified North Fork. N3 and S3 WUA predictions (Tables 3 and 4, respectively) can be compared directly. An example is fall chinook spawning. The WUA prediction for S3 is about 10-1/2 times that for N3. When all respective fish species life stage predictions (except sockeye salmon) are compared, S3 has a mean habitat availability approximately 5 times that of N3. This indicates that the magnitude of loss in the lower North Fork is approximately 80%.

Other North Fork and South Fork study areas represent partitioned reaches too unique to compare directly between rivers. However, the general magnitude of WUA predictions for the South Fork shows that the habitat loss on the North Fork was very great. Approximately one-half of accessible miles on the North Fork were blocked by the Cushman Project.

Mainstem Skokomish River

IFG4 calculations of R^2 for expected versus observed cross-sectional segment velocities at study area S4 ranged from 0.95-1.00, with a mean value of 0.98. Calculations of R^2 for Q series versus stage series equalled 1.00.

Figure 19. Lower South Fork flow-timings compared with the plot of mean monthly discharges (cfs) of an equivalent median flow year. Equivalent median discharges (not exceeded one in two years) larger than the upper limit of the discharge scale are shown above the respective month (Example: ● 1196).

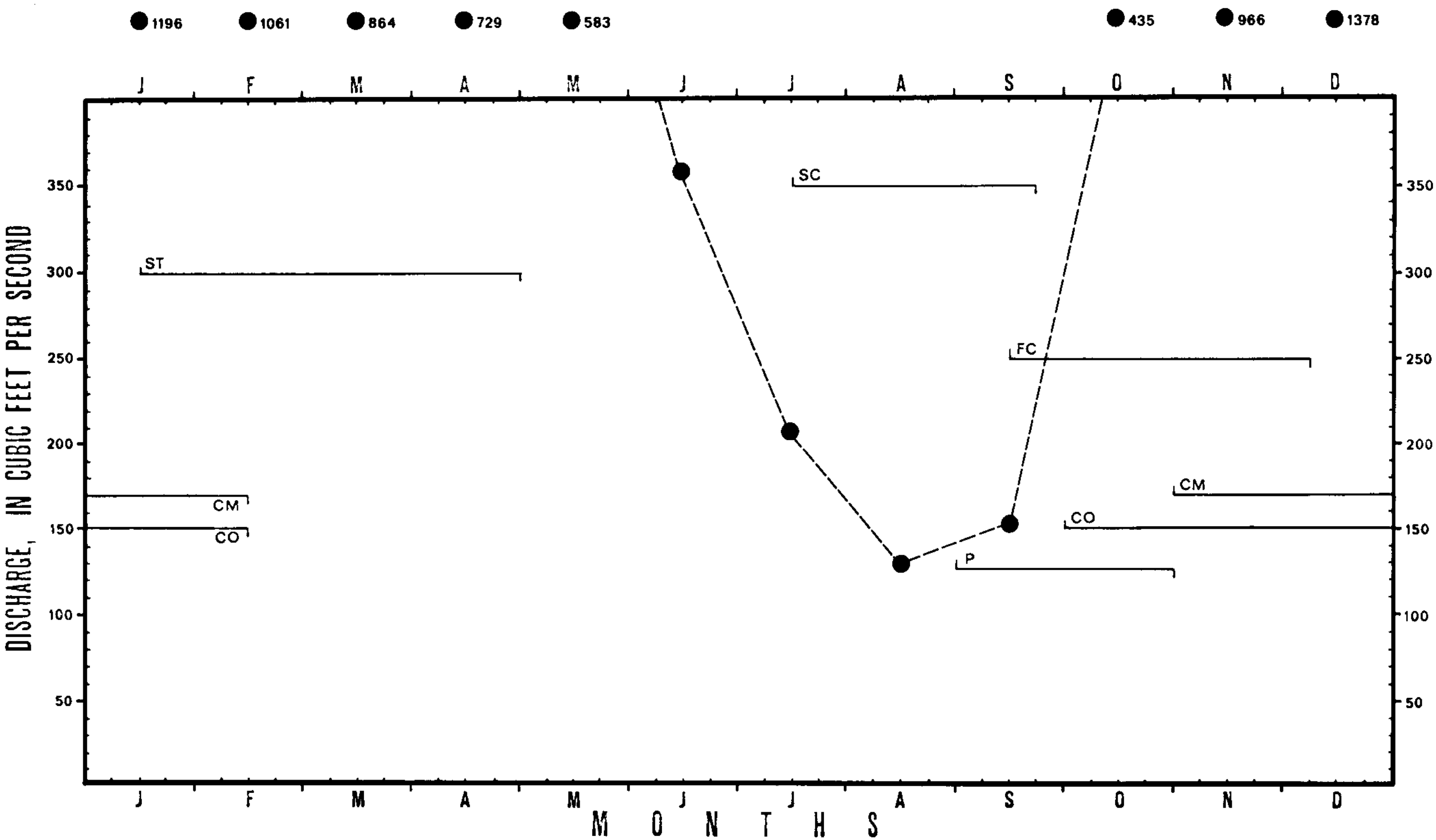
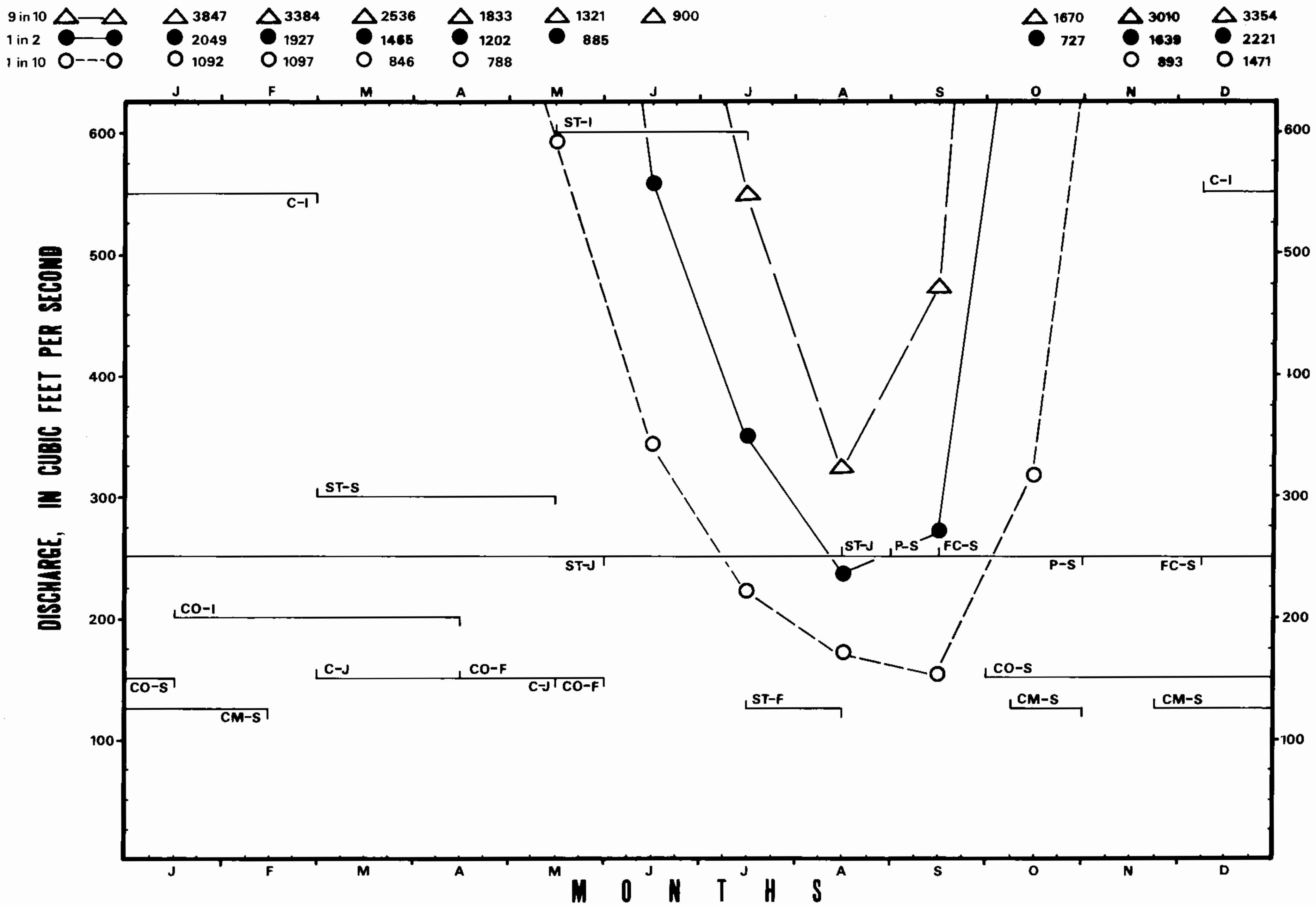


Figure 20. Mainstem Skokomish River flow-timings (from Figure 8 and Table 4) compared with plotted curves of equivalent high (9 in 10), median (1 in 2), and moderately low (1 in 10) flow years. Discharges that exceed graph scales are listed above graph by month.



The predictions for preferred discharges in the mainstem Skokomish River (Table 4) are lower than expected, in view of the comparatively large mean monthly discharges that occur (Appendix Table 16). Averaged mean monthly discharges in the mainstem, during all months, are more than 50% larger than respective South Fork discharges (Appendix Table 15). However, only five of thirteen predictions of preferred discharge (salmon and steelhead) in the mainstem are greater than respective predictions for the lower South Fork (Table 4). All WUA predictions for the mainstem are smaller than respective predictions for the lower South Fork.

Review of study area S4 instream data (by individual parameter), and the habitat criteria curves used, supports the predictions (Table 4) as correct. River substrate is suitable for spawning requirements in about 75% of the study area, but over a majority of the area, that is, square feet within the study area wetted perimeters, either depth or velocity or both depth and velocity are unsuitable. The mainstem river's higher pool : riffle ratio, and more uniformly confined and defined channel shape, together result in a proportionally increased area of channel having increased water depth. The comparison of mainstem equivalent flow year plots to mainstem flow-timings (Figure 20) demonstrates that mean monthly discharges generally fail to provide, during most months and in most years, optimum habitat area.

What the effects would be of North Fork water releases upon fish habitat in the mainstem should be known. The longest period having the largest water release contribution would occur during an equivalent moderately low flow year (Table 7 and Figure 20). No adverse effect of any significance is apparent. The effects during other equivalent flow years, although of shorter duration, appear more adverse. But if the apparent adverse and beneficial effects of release water contributions during respective higher and lower flow years are compared, the resultant effects should balance, in terms of fish habitat. Extra water to satisfy habitat requirements in low flow years should make up for reduced habitat availability during high flow years. One expected effect of increased discharge in the mainstem is for some proportion of fish in spawning migration to pass through the mainstem, enter the North Fork, and utilize the better controlled, optimum habitat conditions created there. The very significant benefits to be gained in the lower North Fork from controlled water releases need not be abandoned due to effects in the mainstem Skokomish River.

CONCLUSIONS

Analysis and comparison of North Fork optimum discharge and habitat area predictions to species/life stage timing and equivalent flow year statistics demonstrates that post-dam discharges are seasonally inadequate for anadromous salmonid needs. During one year in ten, discharges during low flow months have been extremely limiting upon all rearing salmon and winter steelhead. During one year in ten, discharges are so large that for about eight months habitat requirements are at less than optimum level for all anadromous salmonids. During the remaining years of this ten-year statistical period, levels of habitat availability have been intermediate between those of low and high flow years, but still have been inadequate during summer and early fall.

An annual range of mean monthly discharges in the lower North Fork not exceeding 80 cfs in wet months and not less than 25 cfs in dry months can significantly increase suitable habitat availability. One or more anadromous species and respective life stages may be favored by selecting semimonthly discharges that provide optimum suitable habitat area.

Discharge measured by USGS gaging station No. 1205950000 on the lower North Fork should be used to determine when and how much water should be released from Cushman Dam No. 2 to meet optimum discharge requirements of the preferred species. Minimum discharge required to satisfy adult and smolt migration needs through the North Fork critical reach (RM 9.8) should be determined and used to adjust gaging station guidance of dry season water releases.

Rearing habitat in the North Fork upper reach from RM 13.3 (mouth of McTaggert Creek) to the dam should be protected during low runoff months by establishing a minimum water release of 25 cfs. Preferred species optimum habitat needs in the upper reach, during other months, should be protected when feasible; however, optimum habitat needs in the lower reaches (RM 9.0-13.3) should be given first priority.

The pre-dam channel and mean monthly discharges were significantly larger than the existing channel and proposed optimum discharges. Controlling discharges to provide optimum habitat area in the lower North Fork makes best use of the existing channel, and can very significantly increase habitat availability.

In order to carry out above recommendations Cushman Dam No. 2 will require structure/equipment modifications that permit release control accuracy to the nearest 5 cfs.

The lower South Fork reach contains more suitable habitat area than other South Fork reaches. Lower reach habitat is underutilized by anadromous salmonids because prevailing mean monthly discharges exceed those that provide optimum suitable habitat.

Compared North Fork and South Fork WUA predictions indicate an 80% habitat availability loss resulted from dam construction and total flow diversion.

Prevailing mean monthly discharges in the mainstem Skokomish River generally exceed predicted discharges providing optimum habitat area. Discharge contributions from a schedule of water releases at Cushman Dam No. 2, however, are not expected to adversely affect mainstem Skokomish River habitat availability.

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